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EMVA 1288 Data Sheet m0791

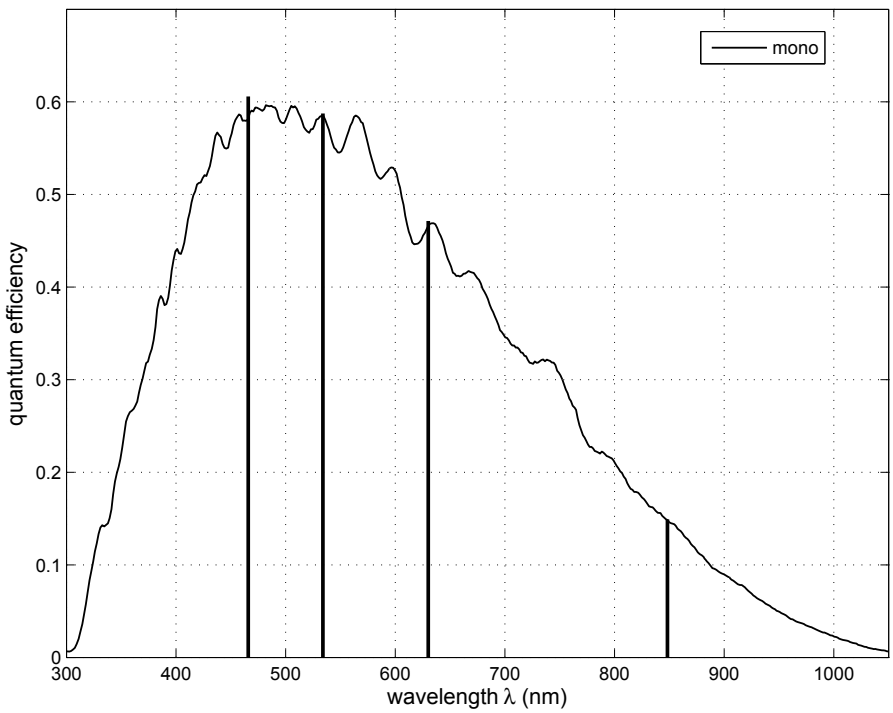
This datasheet describes the specification according to the standard 1288 for "Characterization and Presentation of Specification Data for Image Sensors and Cameras of the European Machine Vision Association (EMVA)" (see `www.standard1288.org` or the *Zenodo EMVA 1288 community*) release 3.0 with proprietary extensions from AEON. The measurements were performed with the AEON ACC2b RGB-IR, Release 5, 27.06.2014, SN 0009(HCI) . The performance parameters and estimated accuracy of the measurements are described in the technical report for the instrument, its calibration in the corresponding specification and calibration report.

Measurements performed by B Jähne, HCI, Heidelberg University and H Herrmann, AEON

Vendor	Basler
Model	acA2500-14gm
Serial number	21130884
Sensor diagonal	7.13 mm
Lens category	C-mount
Resolution	2592 × 1944, 12 bit
Pixel size	2.20 μm × 2.20 μm
Sensor	Aptina MT9P031STM
Sensor type	CMOS
Shutter type	Rolling
Overlap capabilities	Overlapping
Maximum frame rate	14.1 Hz
Interface type	GigE

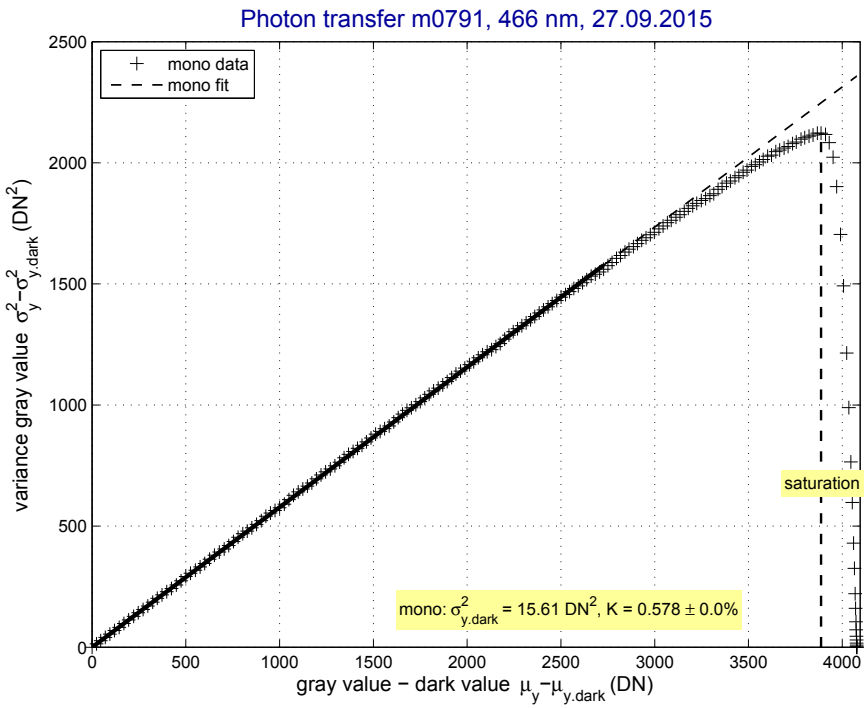
Type of data presented	Single
Operation point 1, (page 6)	
Wavelength centroid	465.8 nm
Wavelength FWHM	20.9 nm
Gain, offset	0, 16
Operation point 2, (page 21)	
Wavelength centroid	533.9 nm
Wavelength FWHM	31.3 nm
Gain, offset	0, 16
Operation point 3, (page 36)	
Wavelength centroid	630.1 nm
Wavelength FWHM	13.2 nm
Gain, offset	0, 16
Operation point 4, (page 51)	
Wavelength centroid	848.2 nm
Wavelength FWHM	19.7 nm
Gain, offset	0, 16
Optional data measured	
Quantum efficiency	full sensor size with 3 nm resolution

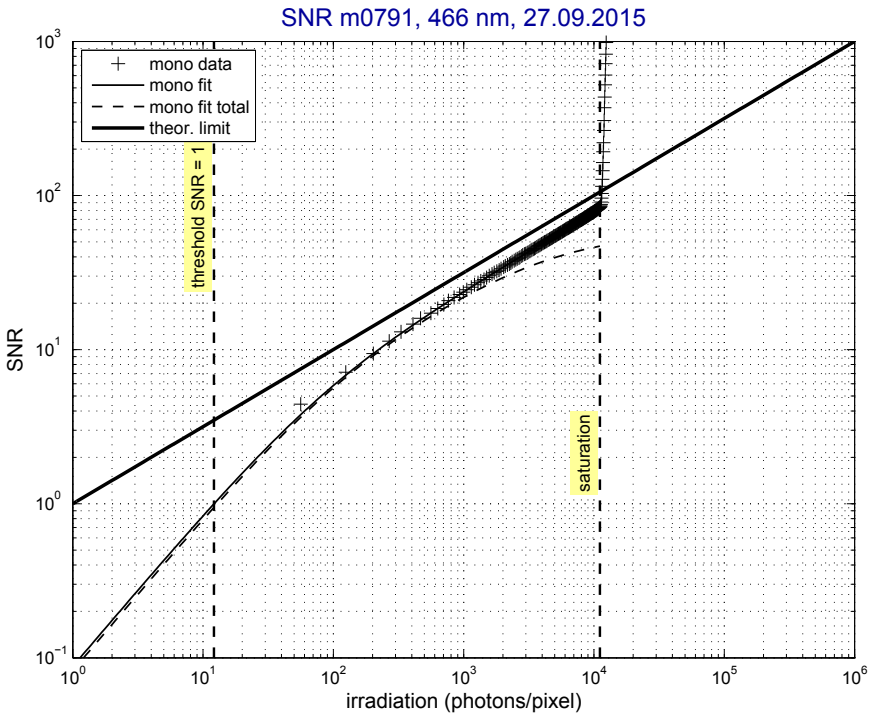
Spectral sensitivity m0799, 28.09.2015



EMVA 1288 Summary Sheet for Operating Point 1

Type of data	Single	Gain, offset	0, 16
Exposure control	by irradiance	Environmental temperature	23.0°C
Exposure time	50.01 ms	Camera body temperature	32.6°C
Frame rate	14.1 Hz	Intern temperature(s)	—
Data transfer mode	Mono 12 Packed	Wavelength, centr., FWHM	466 nm, 20.9 nm





Quantum efficiency

η	60.6%

Overall system gain

K	0.578 DN/e
$1/K$	1.729 e /DN

Temporal dark noise & DSNU

$\sigma_{y.dark}$	3.95 DN
$DSNU_{1288}$	1.45 DN
σ_d	6.81 e
$DSNU_{1288}$	2.50 e

Signal-to-noise ratio & PRNU

SNR_{max}	82
	38.3 dB
	6.4 bit
$1/SNR_{max}$	1.22 %
$PRNU_{1288}$	1.74 %

Nonlinearity

LE	0.29%
LE_{min}	-0.26%
LE_{max}	0.32%

Sensitivity & saturation

$\mu_{p,min}$	12.13 p
	2.507 p/μm^2
$\mu_{p,sat}$	11116 p
	2297 p/μm^2
$\mu_{e,min}$	7.35 e
	1.519 e /μm^2
$\mu_{e,sat}$	6735 e
	1391 e /μm^2

Dynamic range

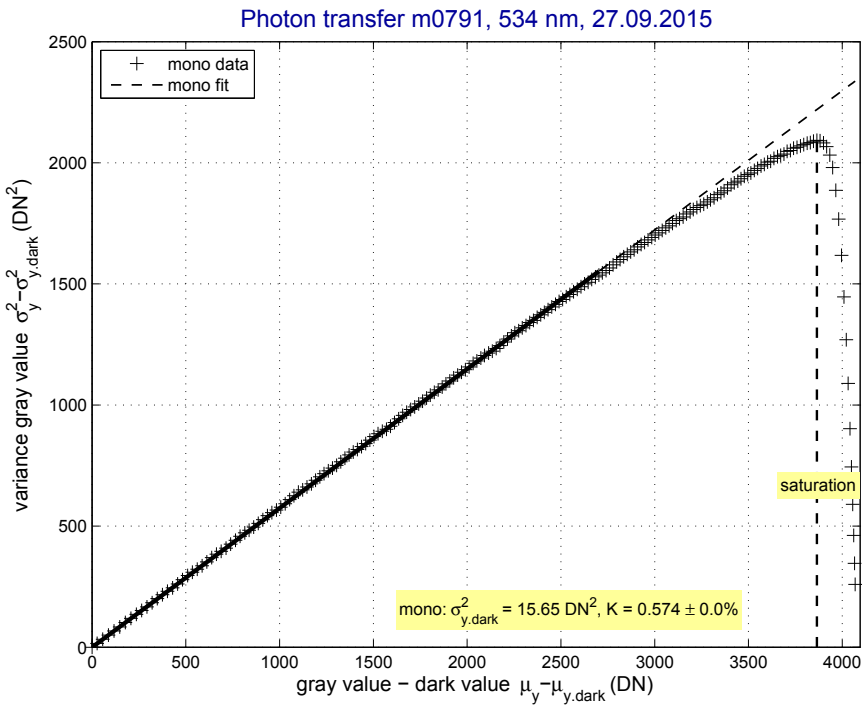
DR	916
	59.2 dB
	9.8 bit

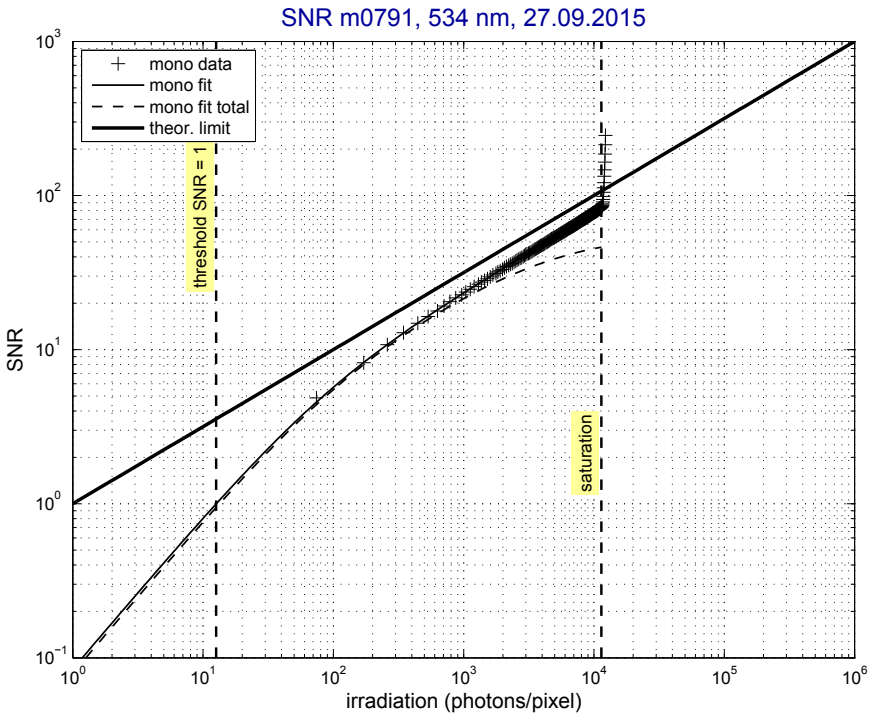
Dark current

$\mu_{c,mean}$	1.8 DN/s
$\mu_{c,mean}$	3.1 e /s
$\mu_{c,var}$	10.7 e /s

EMVA 1288 Summary Sheet for Operating Point 2

Type of data	Single	Gain, offset	0, 16
Exposure control	by irradiance	Environmental temperature	23.0°C
Exposure time	50.01 ms	Camera body temperature	32.6°C
Frame rate	14.1 Hz	Intern temperature(s)	—
Data transfer mode	Mono 12 Packed	Wavelength, centr., FWHM	534 nm, 31.3 nm





Quantum efficiency

η	58.8%

Overall system gain

K	0.574 DN/e
$1/K$	1.741 e /DN

Temporal dark noise & DSNU

$\sigma_{\text{y.dark}}$	3.96 DN
DSNU_{1288}	1.45 DN
σ_{d}	6.87 e
DSNU_{1288}	2.53 e

Signal-to-noise ratio & PRNU

SNR_{max}	82
	38.3 dB
	6.4 bit
$1/\text{SNR}_{\text{max}}$	1.22 %
PRNU_{1288}	1.78 %

Nonlinearity

LE	0.26%
LE_{min}	-0.21%
LE_{max}	0.31%

Sensitivity & saturation

$\mu_{p,\text{min}}$	12.61 p
	2.605 p/μm^2
$\mu_{p,\text{sat}}$	11398 p
	2355 p/μm^2
$\mu_{e,\text{min}}$	7.41 e
	1.530 e /μm^2
$\mu_{e,\text{sat}}$	6696 e
	1384 e /μm^2

Dynamic range

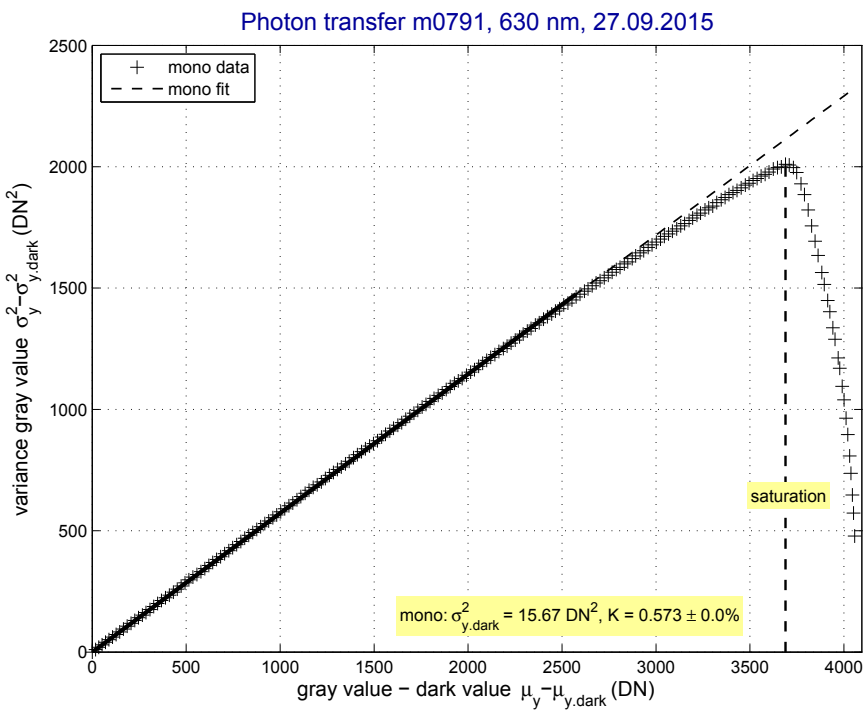
DR	904
	59.1 dB
	9.8 bit

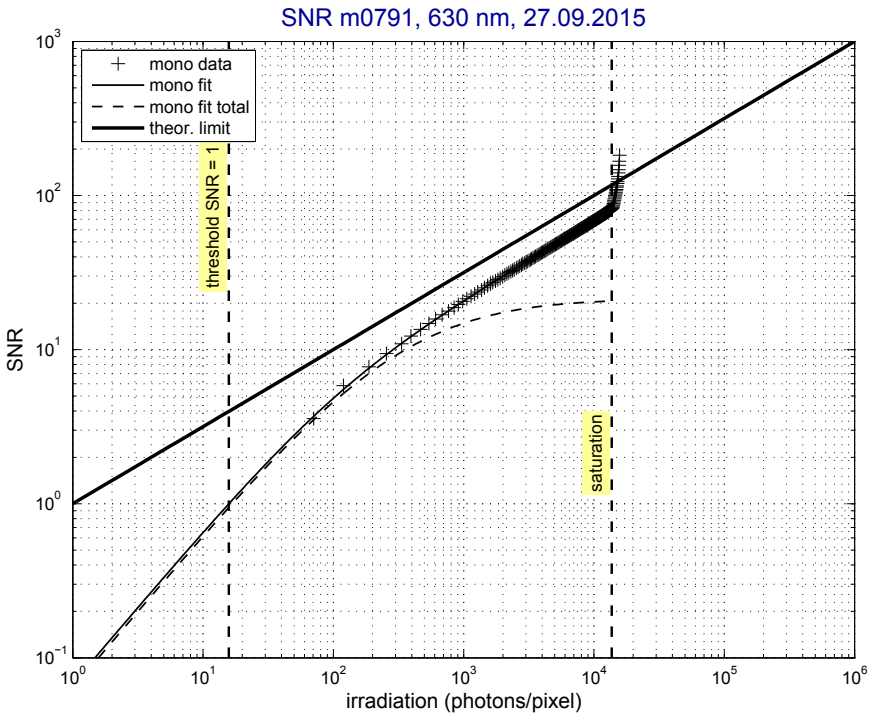
Dark current

$\mu_{c,\text{mean}}$	— DN/s
$\mu_{c,\text{mean}}$	— e /s
$\mu_{c,\text{var}}$	— e /s

EMVA 1288 Summary Sheet for Operating Point 3

Type of data	Single	Gain, offset	0, 16
Exposure control	by irradiance	Environmental temperature	23.0°C
Exposure time	50.01 ms	Camera body temperature	32.6°C
Frame rate	14.1 Hz	Intern temperature(s)	—
Data transfer mode	Mono 12 Packed	Wavelength, centr., FWHM	630 nm, 13.2 nm





Quantum efficiency

η	47.1%

Overall system gain

K	0.573 DN/e
$1/K$	1.746 e /DN

Temporal dark noise & DSNU

$\sigma_{y.dark}$	3.96 DN
$DSNU_{1288}$	1.45 DN
σ_d	6.89 e
$DSNU_{1288}$	2.53 e

Signal-to-noise ratio & PRNU

SNR_{max}	80
	38.1 dB
	6.3 bit
$1/SNR_{max}$	1.25 %
$PRNU_{1288}$	4.67 %

Nonlinearity

LE	0.15%
LE_{min}	-0.14%
LE_{max}	0.15%

Sensitivity & saturation

$\mu_{p,min}$	15.76 p
	3.256 p/μm^2
$\mu_{p,sat}$	13675 p
	2825 p/μm^2
$\mu_{e,min}$	7.43 e
	1.535 e /μm^2
$\mu_{e,sat}$	6446 e
	1332 e /μm^2

Dynamic range

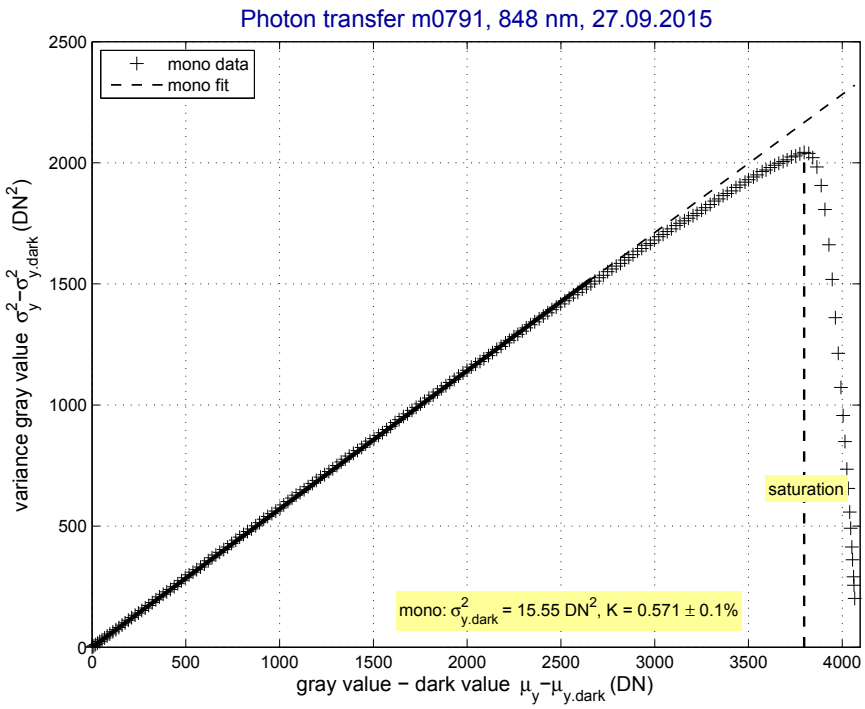
DR	868
	58.8 dB
	9.8 bit

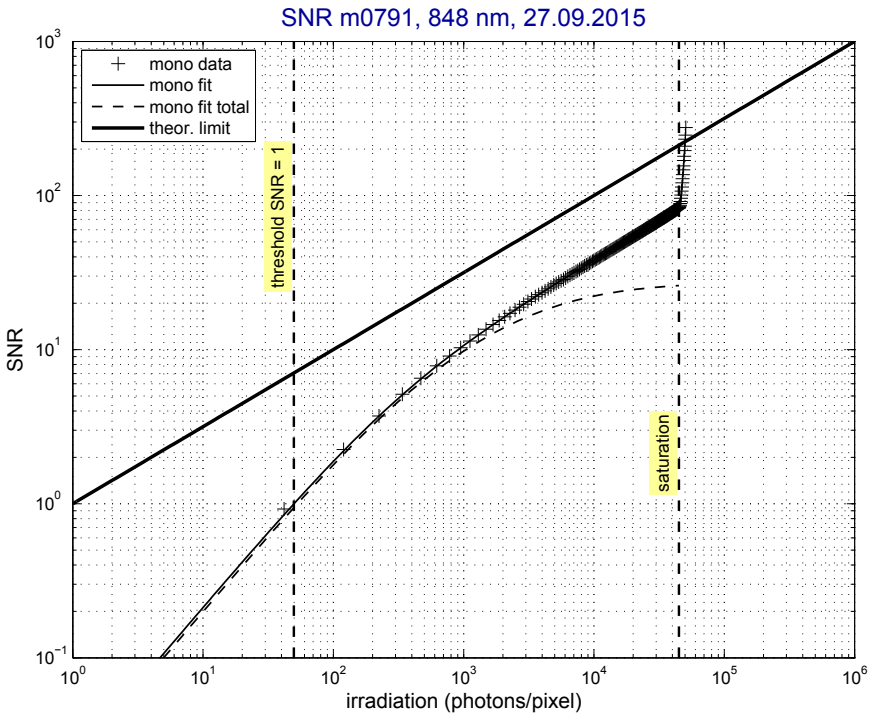
Dark current

$\mu_{c,mean}$	— DN/s
$\mu_{c,mean}$	— e /s
$\mu_{c,var}$	— e /s

EMVA 1288 Summary Sheet for Operating Point 4

Type of data	Single	Gain, offset	0, 16
Exposure control	by irradiance	Environmental temperature	23.0°C
Exposure time	50.01 ms	Camera body temperature	32.6°C
Frame rate	14.1 Hz	Intern temperature(s)	—
Data transfer mode	Mono 12 Packed	Wavelength, centr., FWHM	848 nm, 19.7 nm





Quantum efficiency

η	14.9%

Overall system gain

K	0.571 DN/e
$1/K$	1.752 e /DN

Temporal dark noise & DSNU

$\sigma_{y.dark}$	3.94 DN
$DSNU_{1288}$	1.46 DN
σ_d	6.89 e
$DSNU_{1288}$	2.56 e

Signal-to-noise ratio & PRNU

SNR_{max}	82
	38.3 dB
	6.4 bit
$1/SNR_{max}$	1.22 %
$PRNU_{1288}$	3.64 %

Nonlinearity

LE	0.18%
LE_{min}	-0.24%
LE_{max}	0.11%

Sensitivity & saturation

$\mu_{p,min}$	49.80 p
	10.288 p/μm^2
$\mu_{p,sat}$	44842 p
	9265 p/μm^2
$\mu_{e,min}$	7.43 e
	1.535 e /μm^2
$\mu_{e,sat}$	6689 e
	1382 e /μm^2

Dynamic range

DR	901
	59.1 dB
	9.8 bit

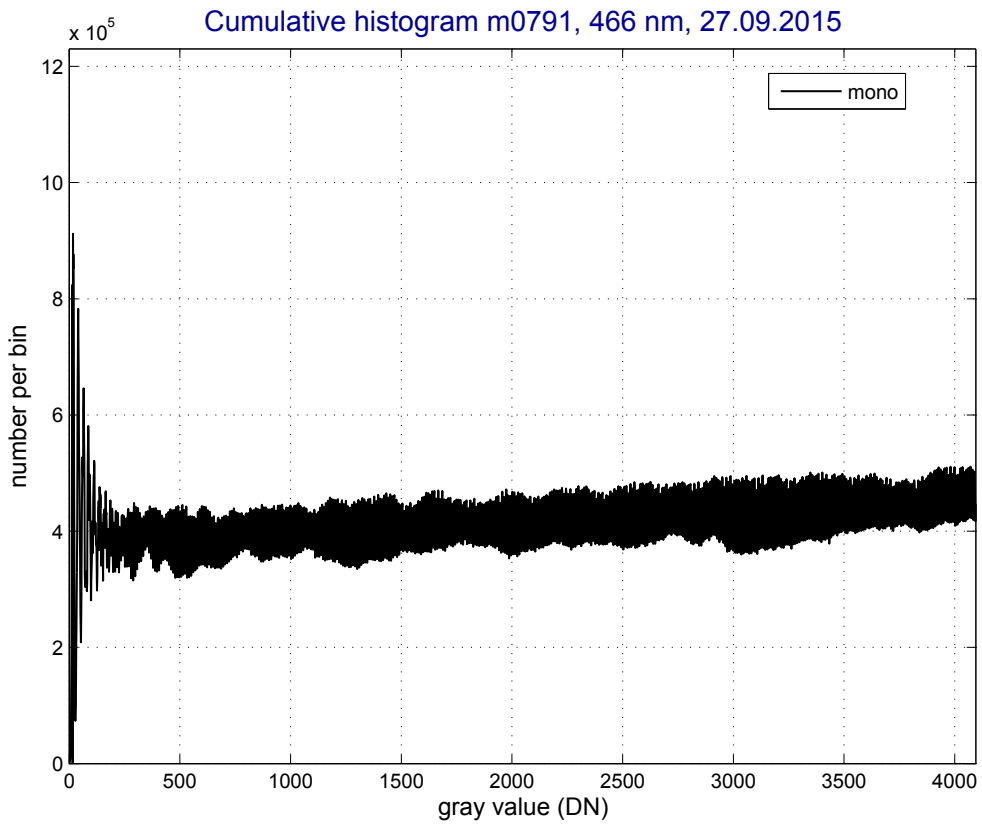
Dark current

$\mu_{c,mean}$	— DN/s
$\mu_{c,mean}$	— e /s
$\mu_{c,var}$	— e /s

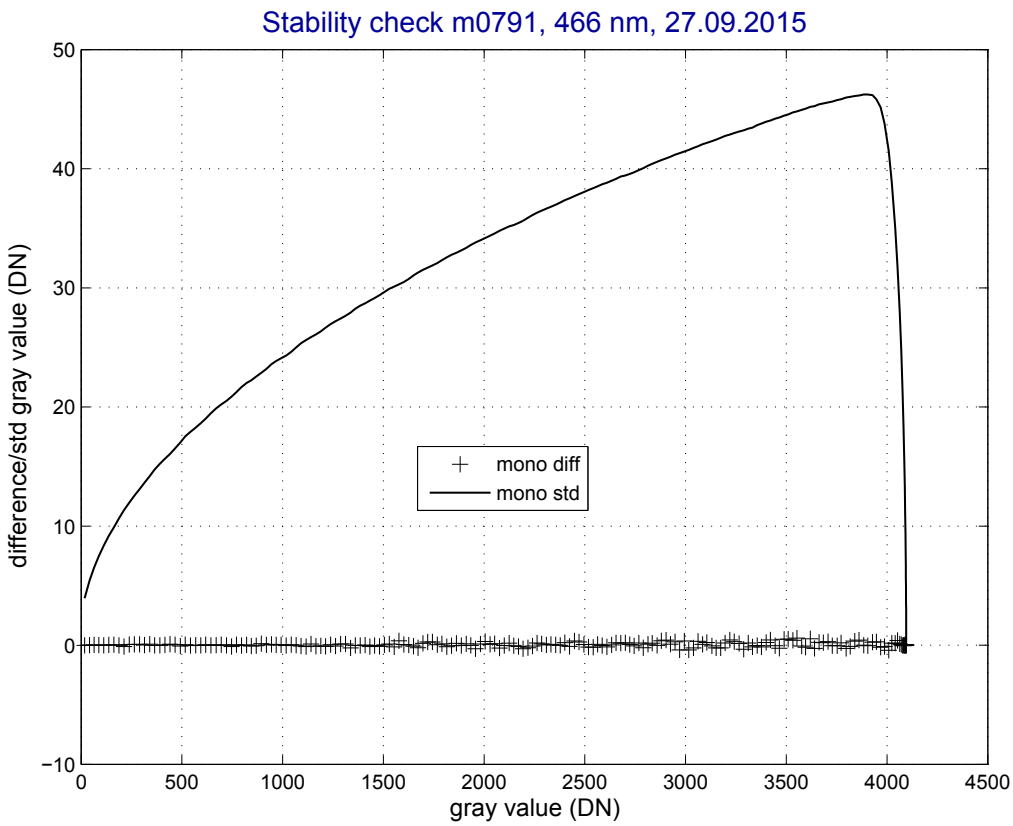
Detailed Data Operating Point 1, 466 nm

Contents

1.1 Checks for Correctness of Measurements and EMVA 1288 Model



Gray value histogram accumulated over all illumination steps (plot in extension of EMVA1288 standard).



Stability check: temporal standard deviation (line) and difference of mean of two images (crosses) for all illumination steps (plot in extension of EMVA1288 standard).

Covariance coefficients of neighboring pixels averaged over the whole image sensor. Values unequal zero except for coefficient without shift, which is one, indicate some kind of preprocessing. This makes the central assumption of the linear EMVA 1288 model invalid. The gain K will then be lower and the quantum efficiency η higher than the true values.

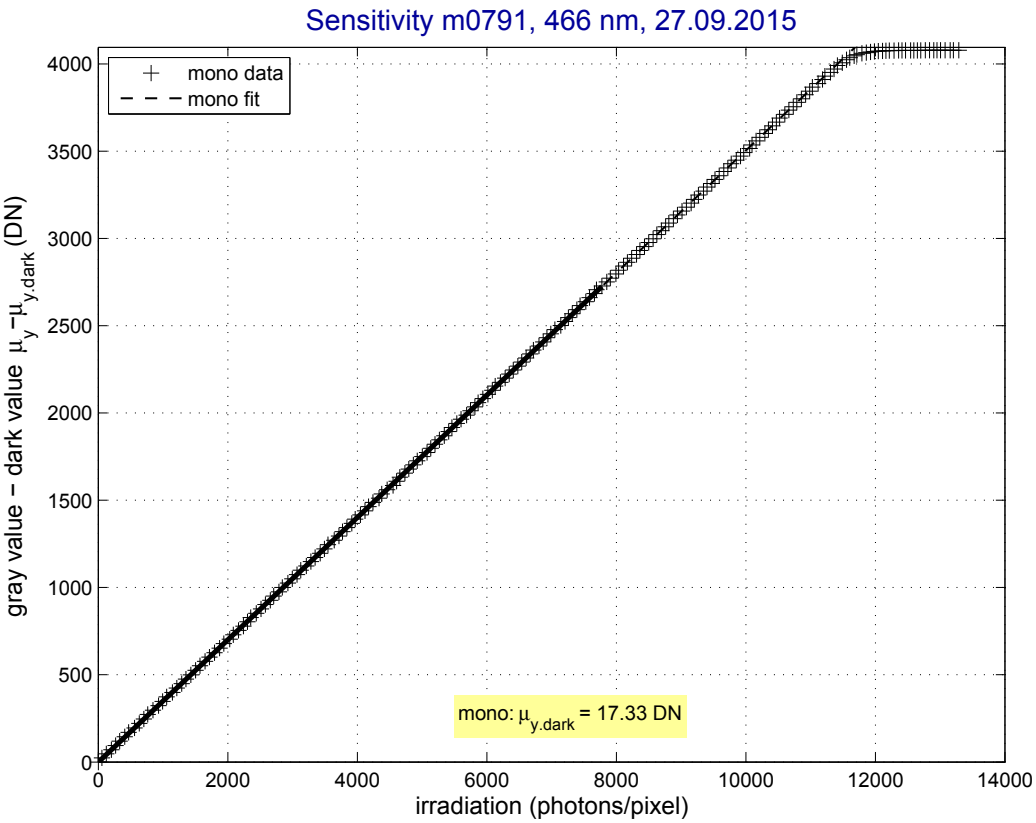
List of covariance coefficients in 9×9 neighborhood, dark image (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.001	0.017	0.000	0.040	0.001	0.024	0.000	0.040
0.005	0.000	0.005	0.001	0.006	0.001	0.005	0.000	0.006
0.002	0.000	0.007	0.000	0.005	0.000	0.008	0.001	0.008
0.006	0.001	0.005	0.001	0.005	0.001	0.006	0.000	0.005
0.008	0.000	0.007	0.000	0.006	0.000	0.007	0.001	0.004
0.004	0.000	0.006	0.002	0.006	0.001	0.005	0.001	0.004
0.004	0.001	0.005	0.000	0.006	0.001	0.006	0.001	0.008
0.006	0.000	0.004	0.001	0.006	0.001	0.003	0.001	0.006
0.010	0.001	0.008	0.001	0.005	0.000	0.005	0.000	0.003

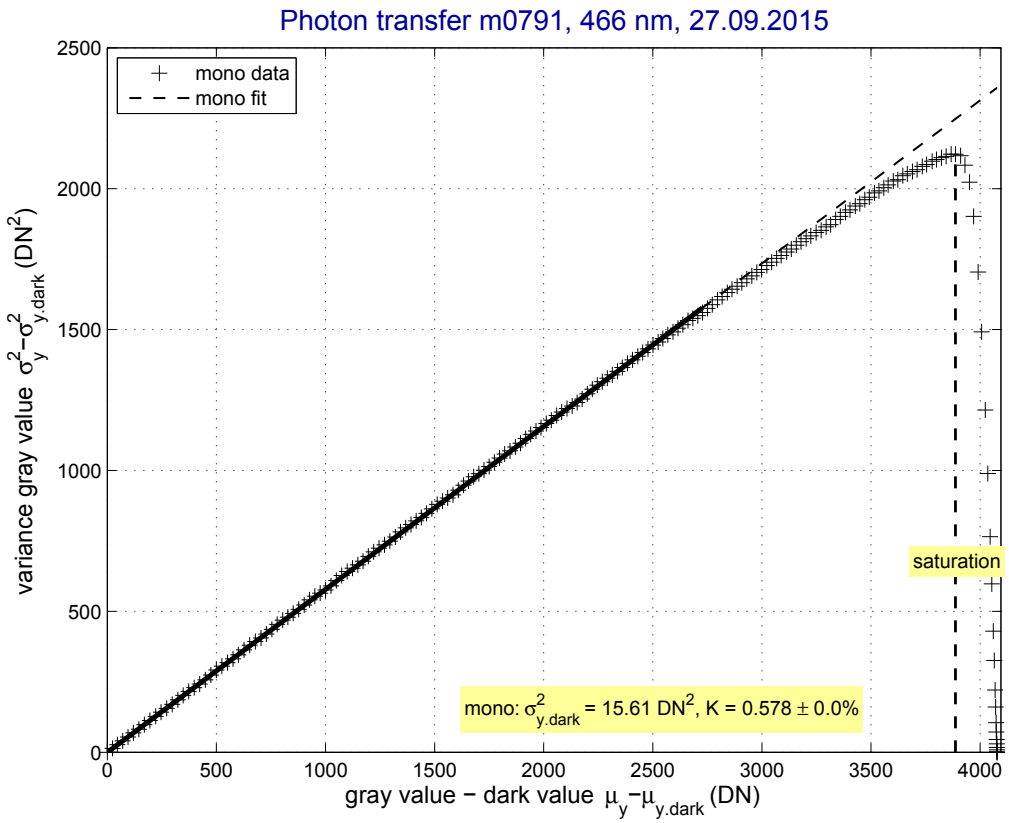
List of covariance coefficients in 9×9 neighborhood, 70% saturation (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.009	0.034	0.001	0.005	0.000	0.000	0.000	0.001
0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000
0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
0.000	0.001	0.000	0.001	0.001	0.000	0.001	0.000	0.001
0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001

1.2 Sensitivity and Noise

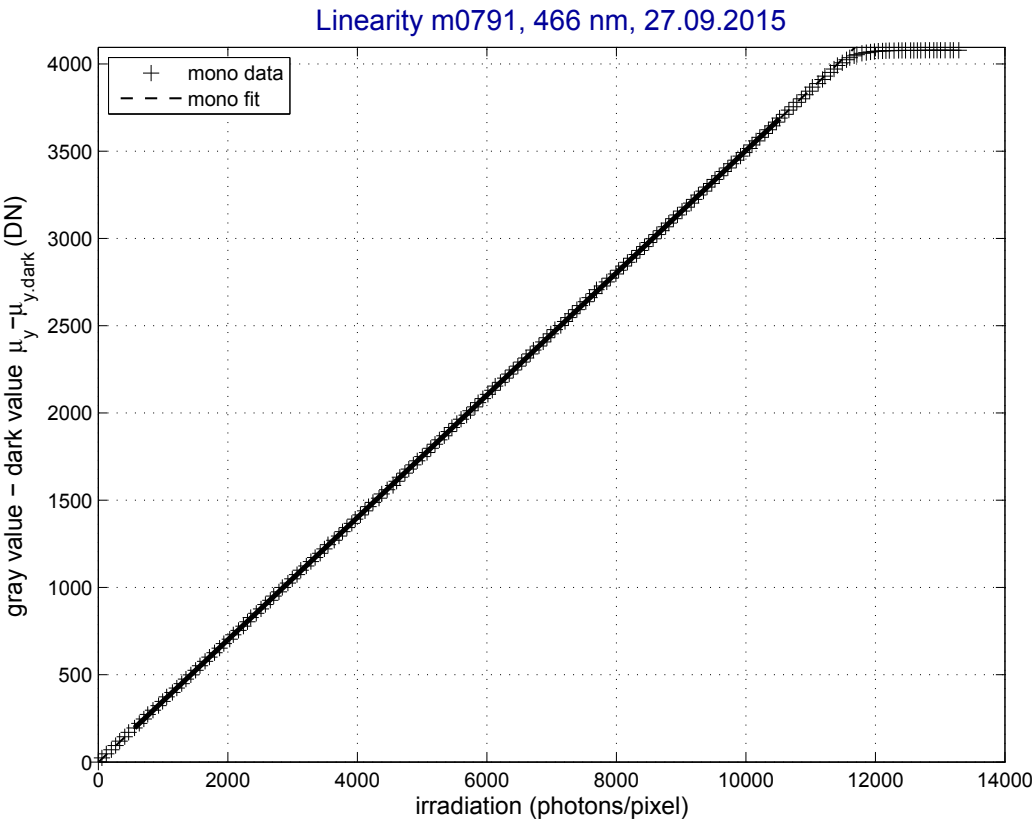


Characteristics camera curve (sensitivity plot) with 201 illumination steps.

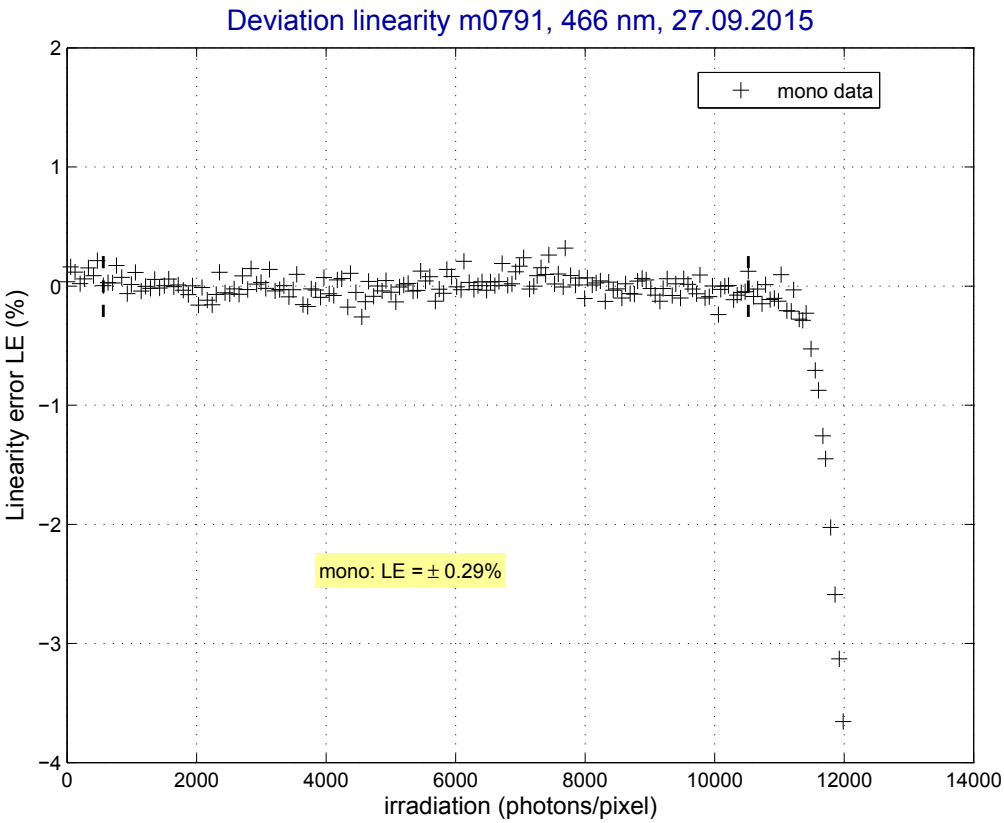


Photon transfer curve with 201 illumination steps.

1.3 Linearity

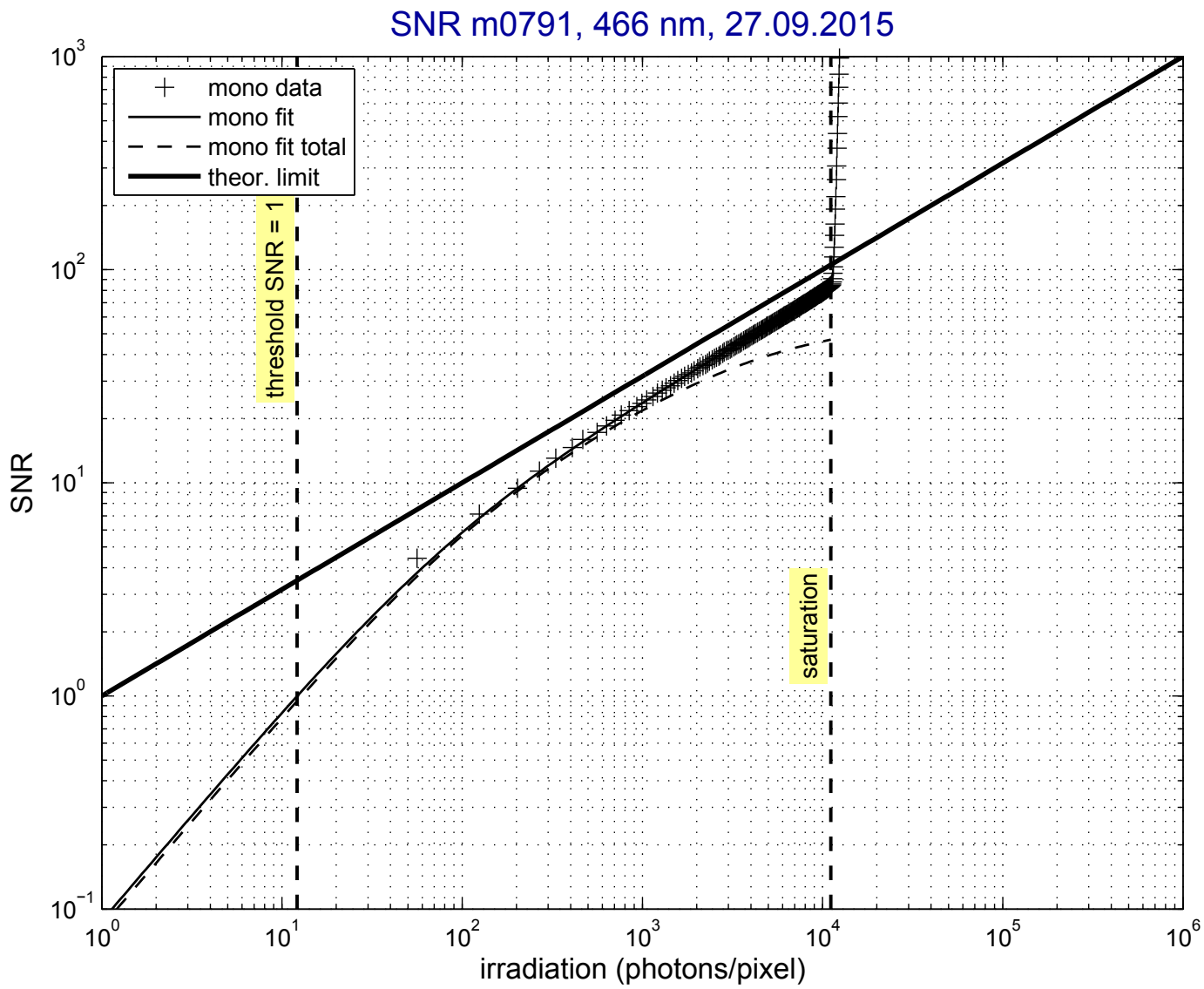


Linearity curve.



Deviation from linearity.

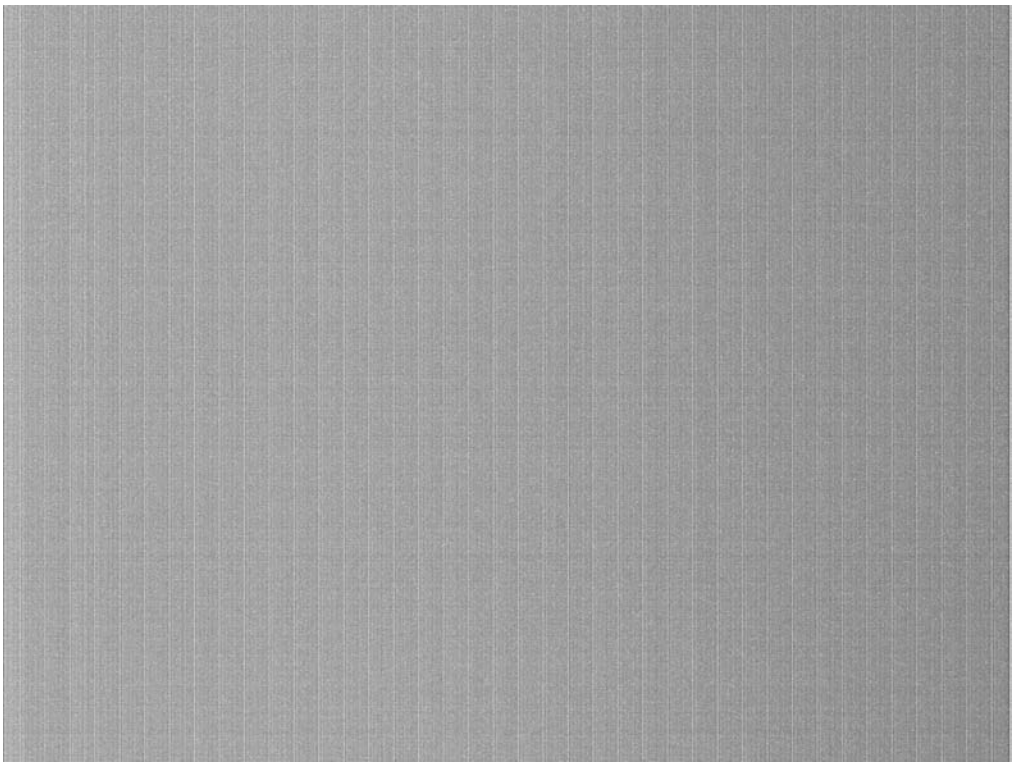
1.4 Signal-to-Noise Ratio (SNR)



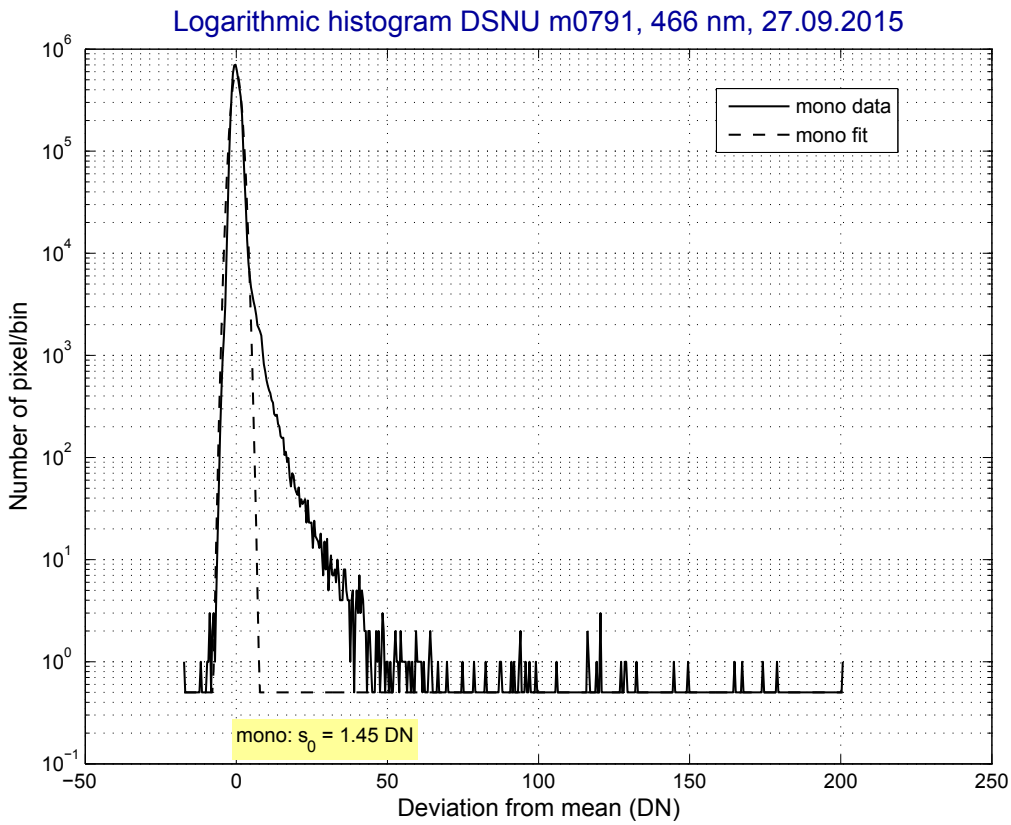
Signal-to-noise ratio in double-logarithmic presentation.

1.5 Nonuniformity: DSNU, PRNU, profiles, spectograms

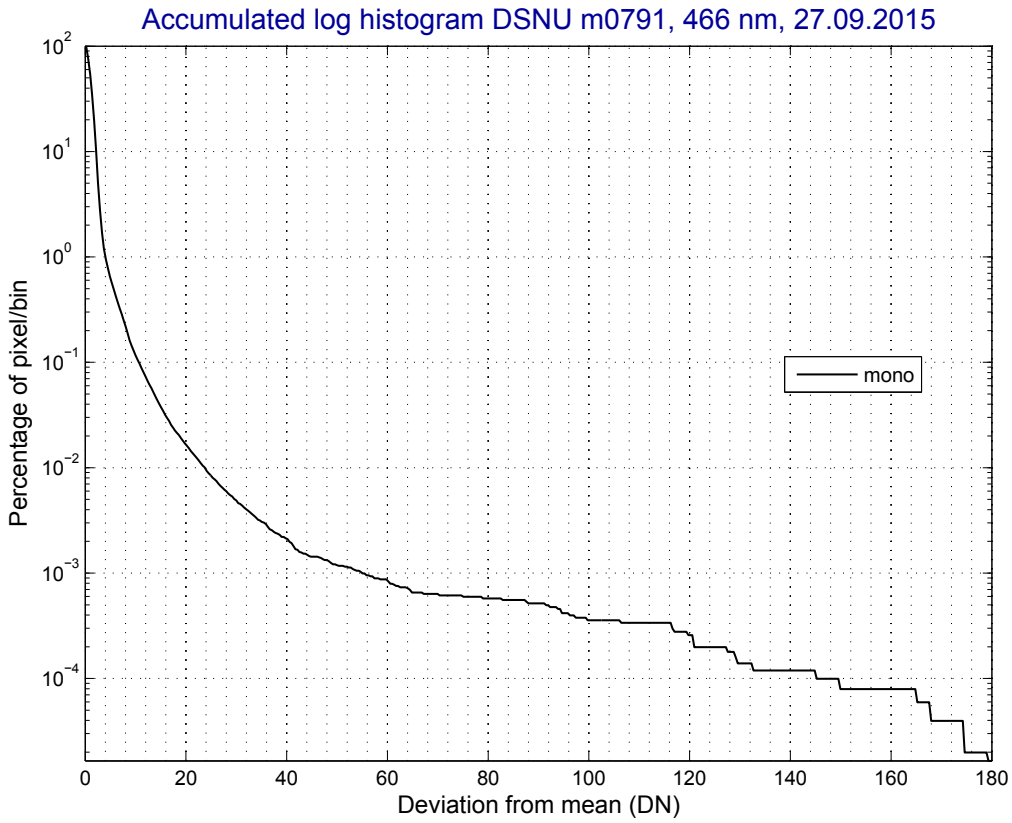
DSNU



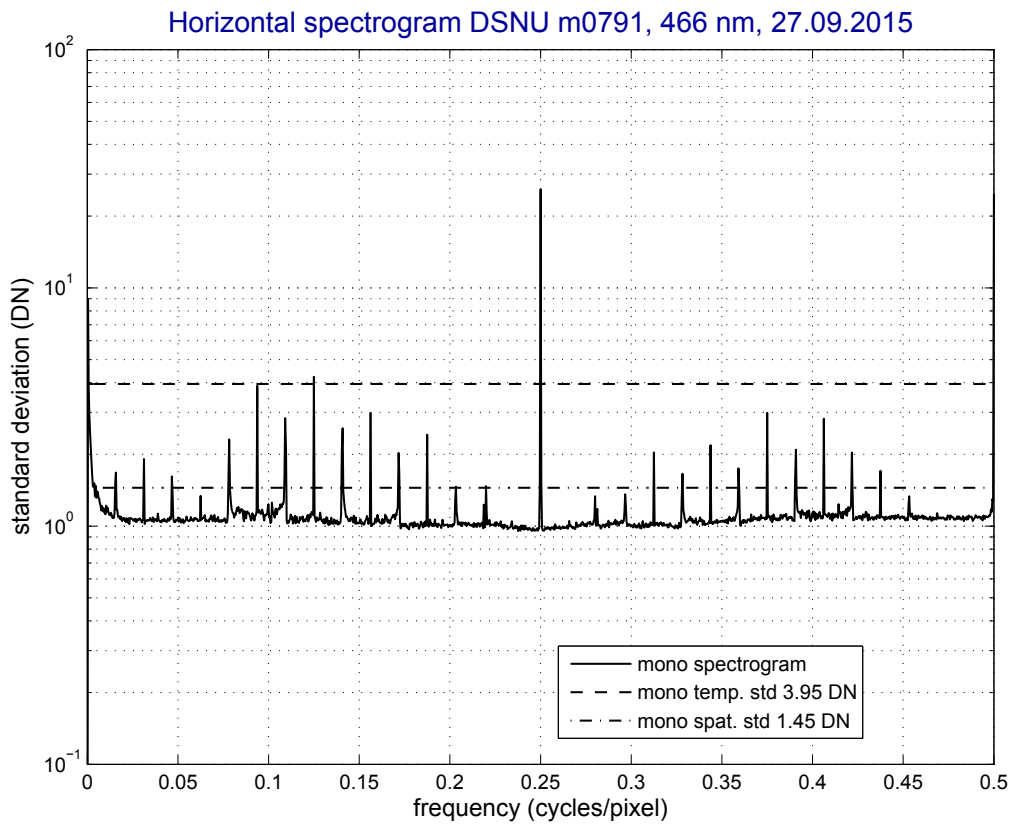
Contrast enhanced dark image, range 13.0 - 21.7 DN (not part of EMVA 1288 standard).



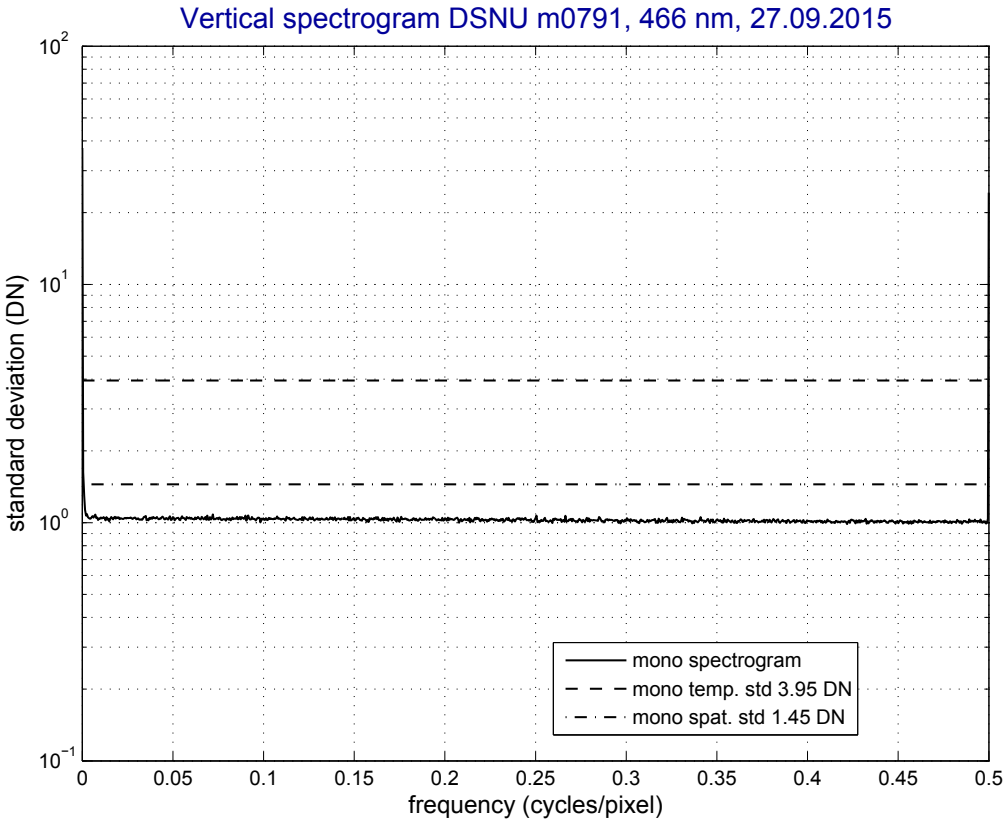
Logarithmic histogram of spatial deviation from mean in units DN.



Accumumulated logarithmic histogram of absolute spatial deviation from mean in units DN.

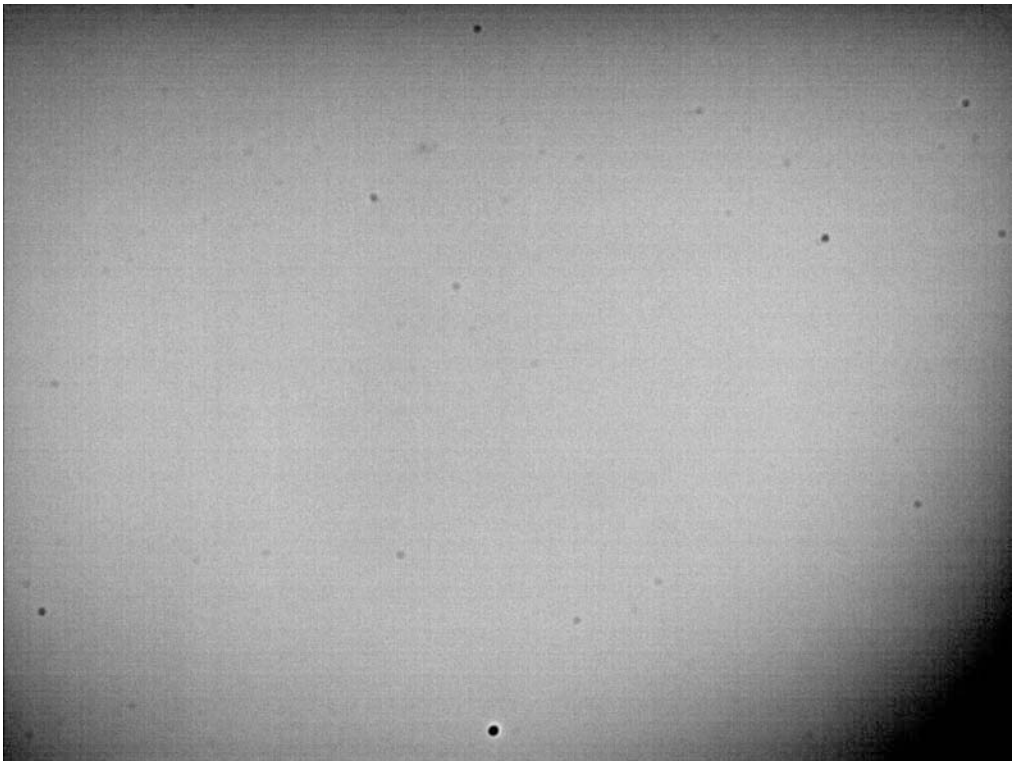


Horizontal spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

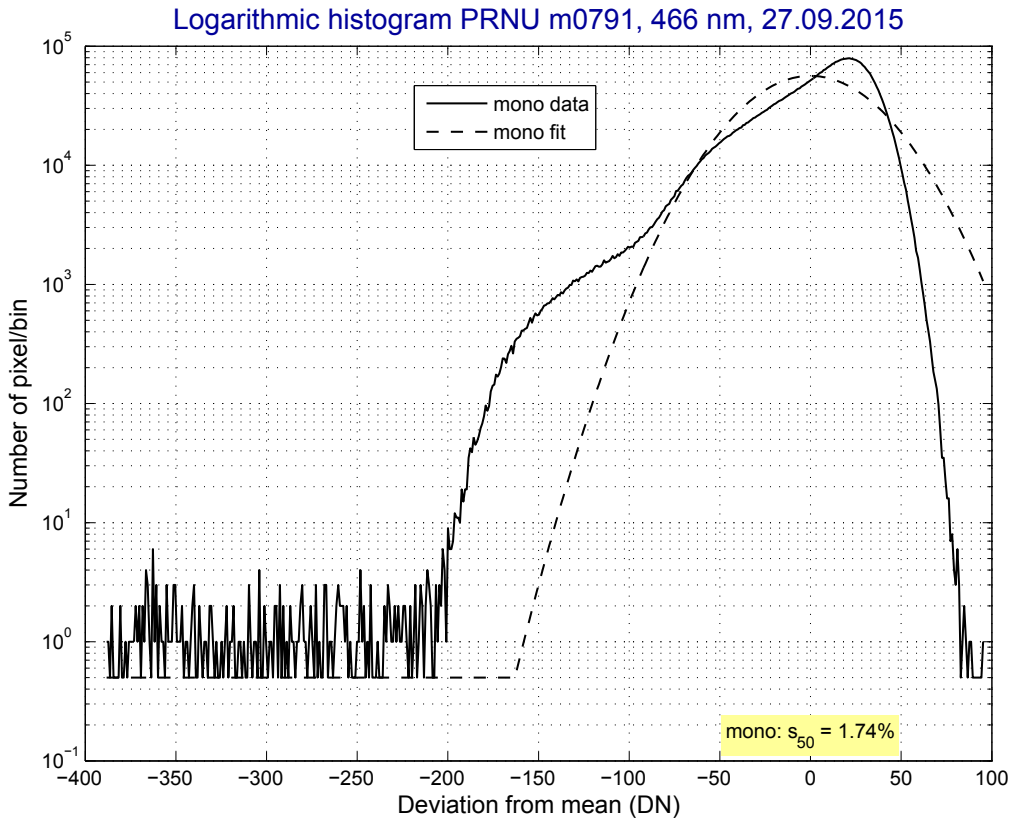


Vertical spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

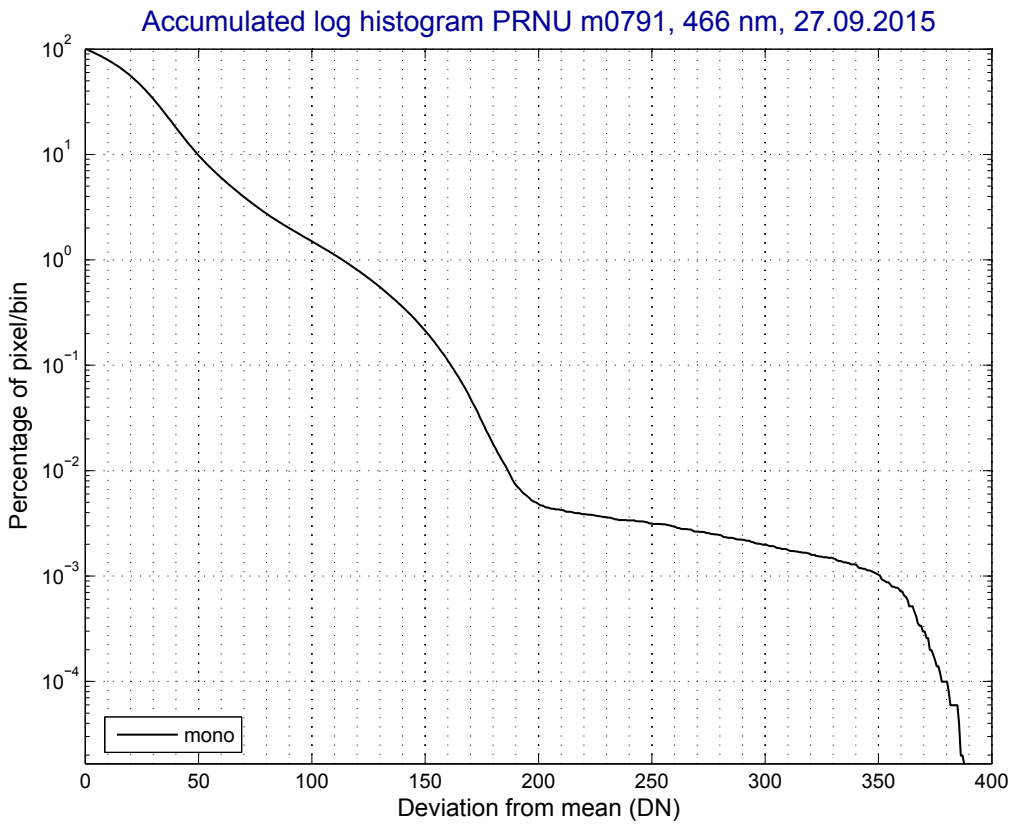
PRNU



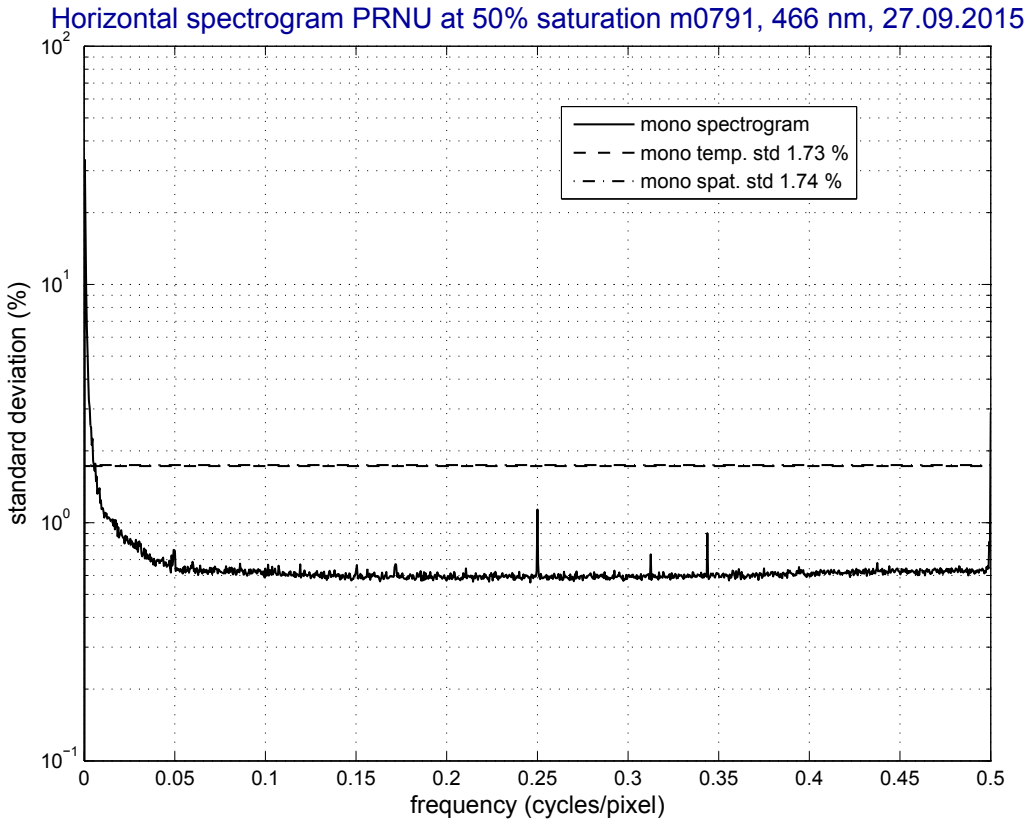
Contrast enhanced response image, range ±5.2% (not part of EMVA 1288 standard).



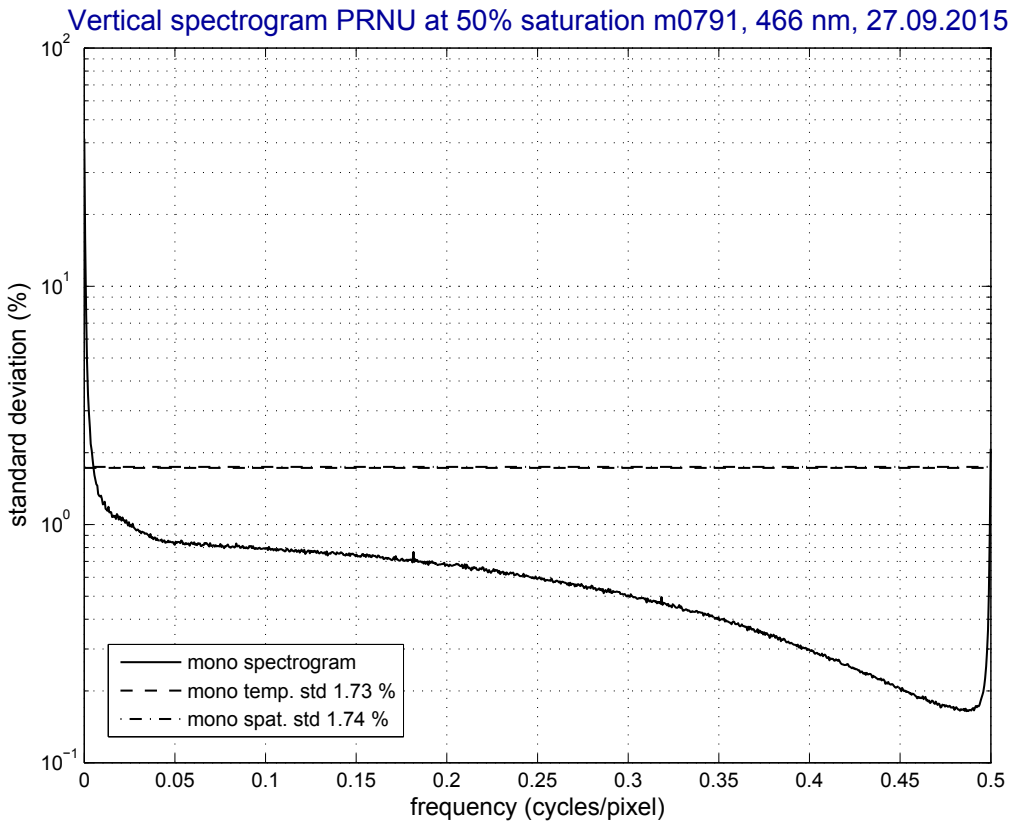
Logarithmic histogram of spatial deviation from mean in units %



Accumulated logarithmic histogram of absolute spatial deviation from mean in units %

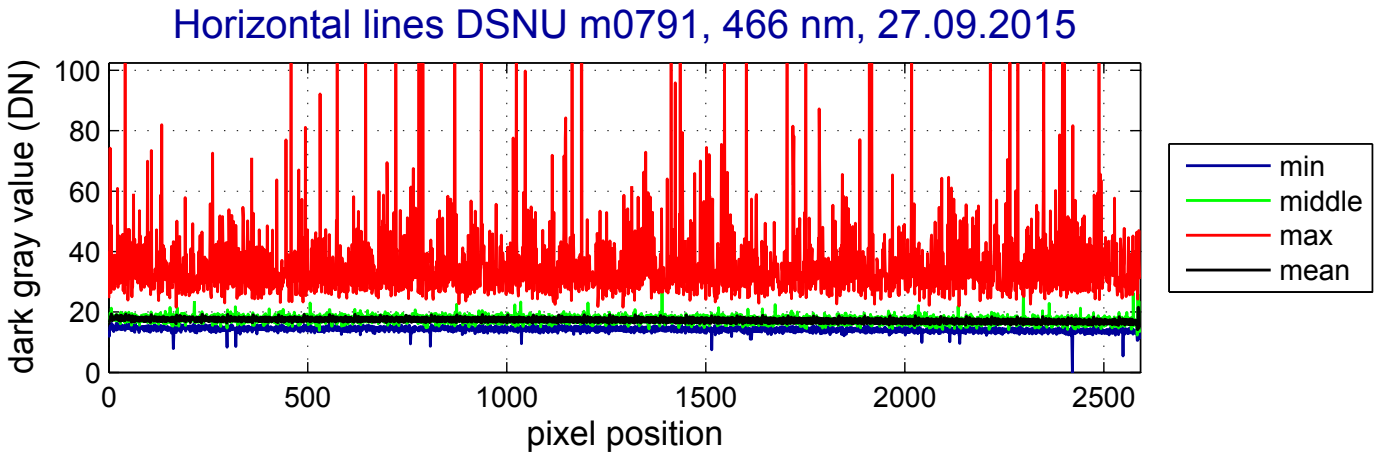


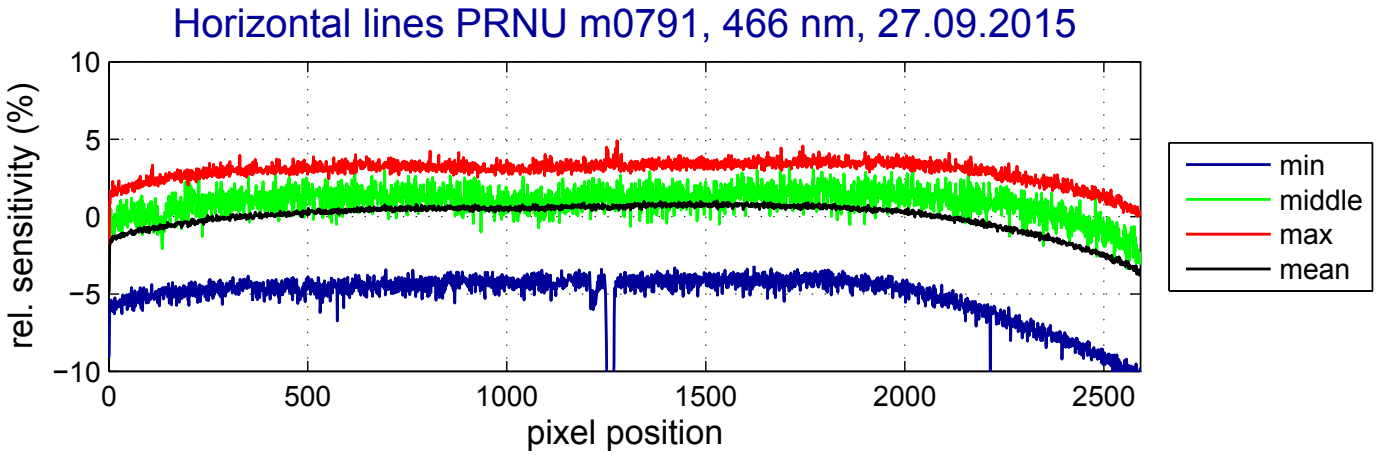
Horizontal spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.076%.



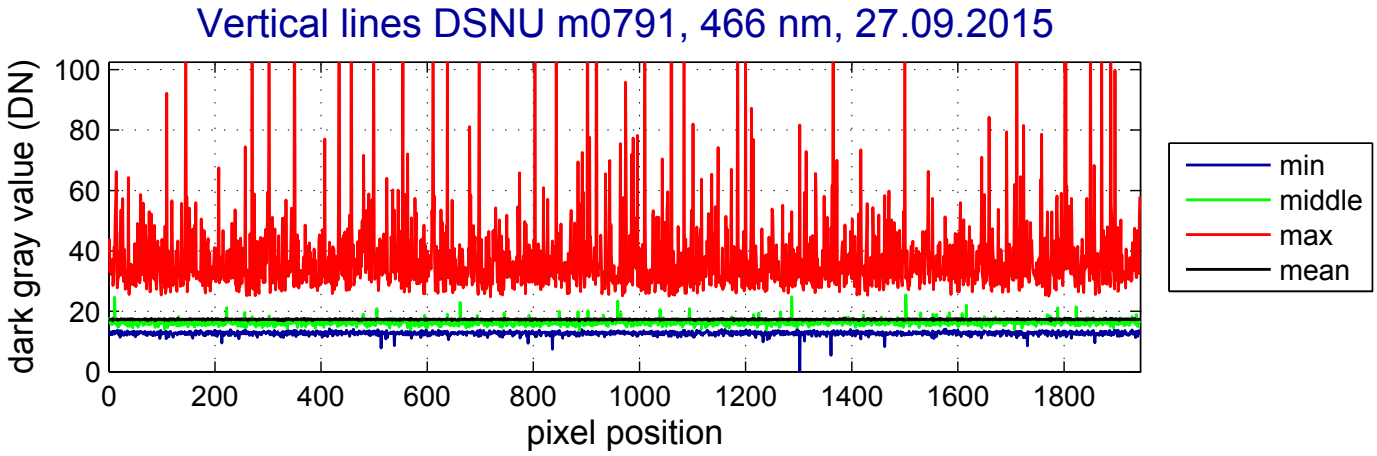
Vertical spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.076%.

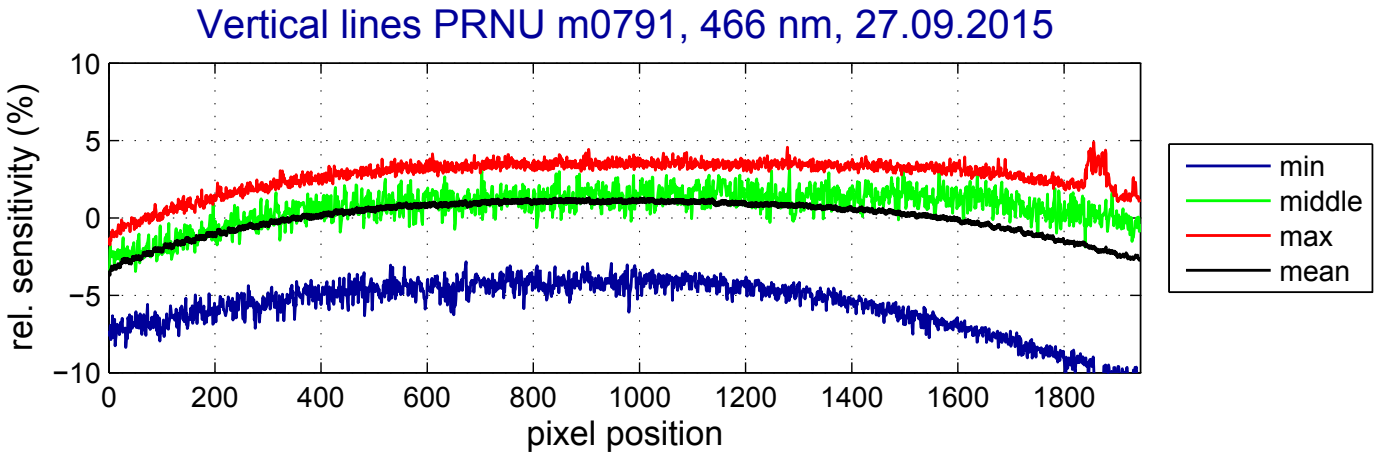
Horizontal and vertical profiles (preliminary, release 3.1)





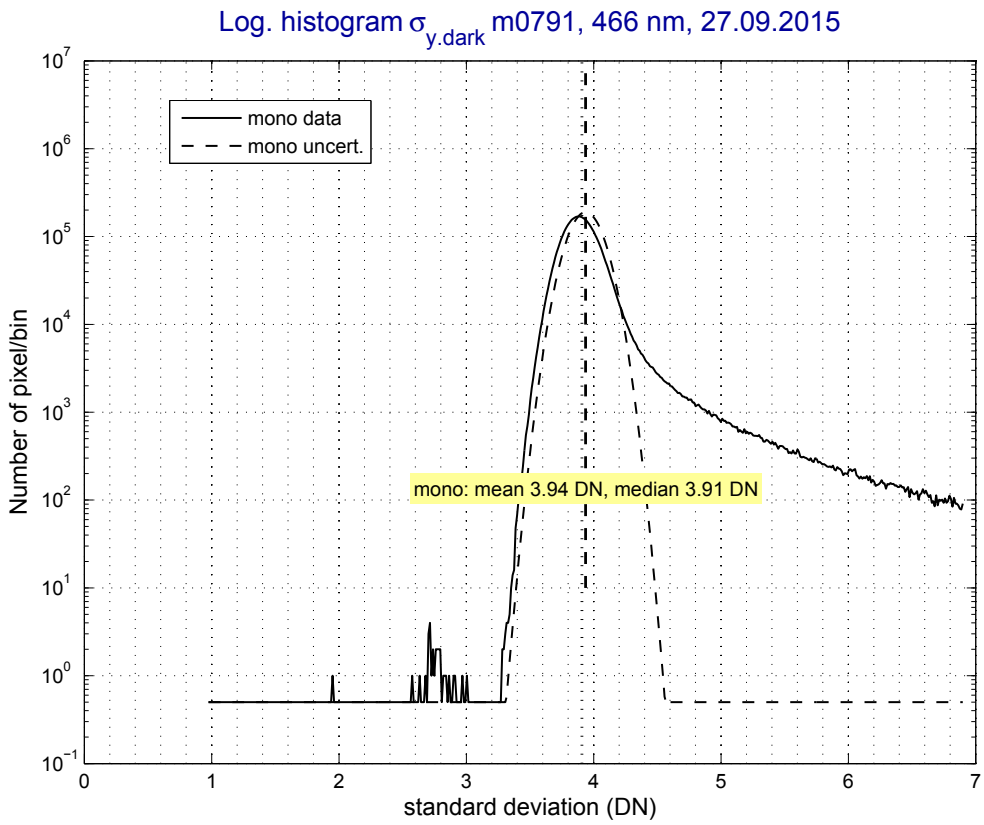
Horizontal profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.



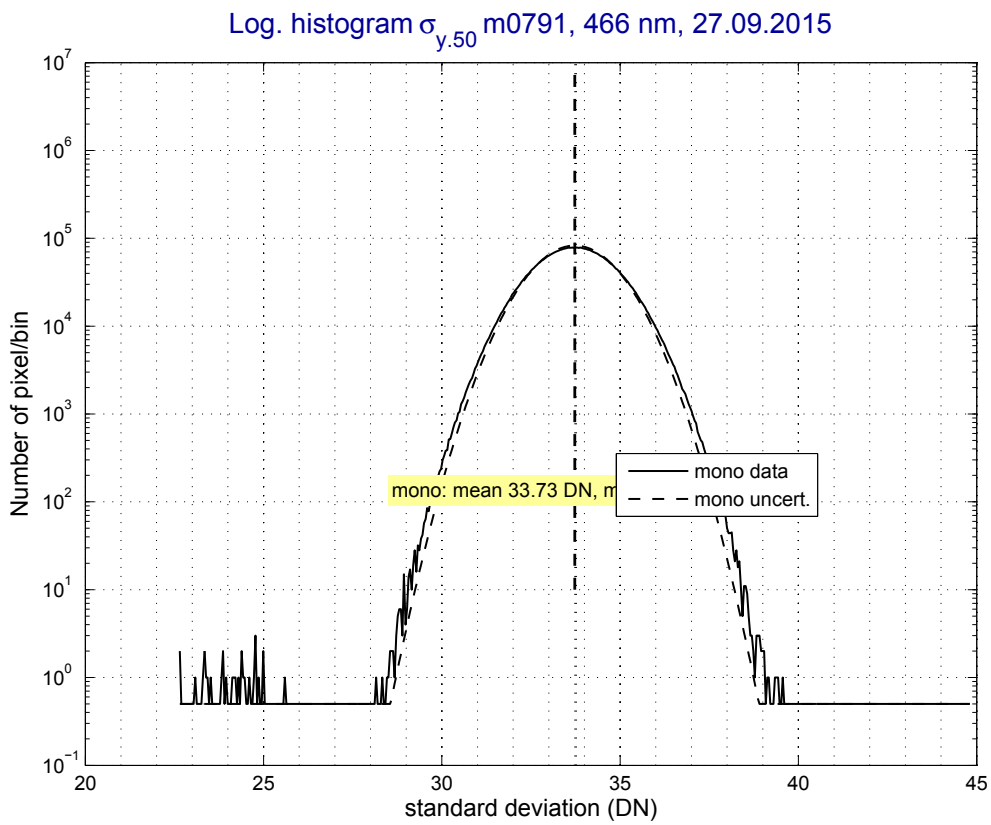


Vertical profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.

Spatial variation of temporal noise (extension to EMVA 1288)

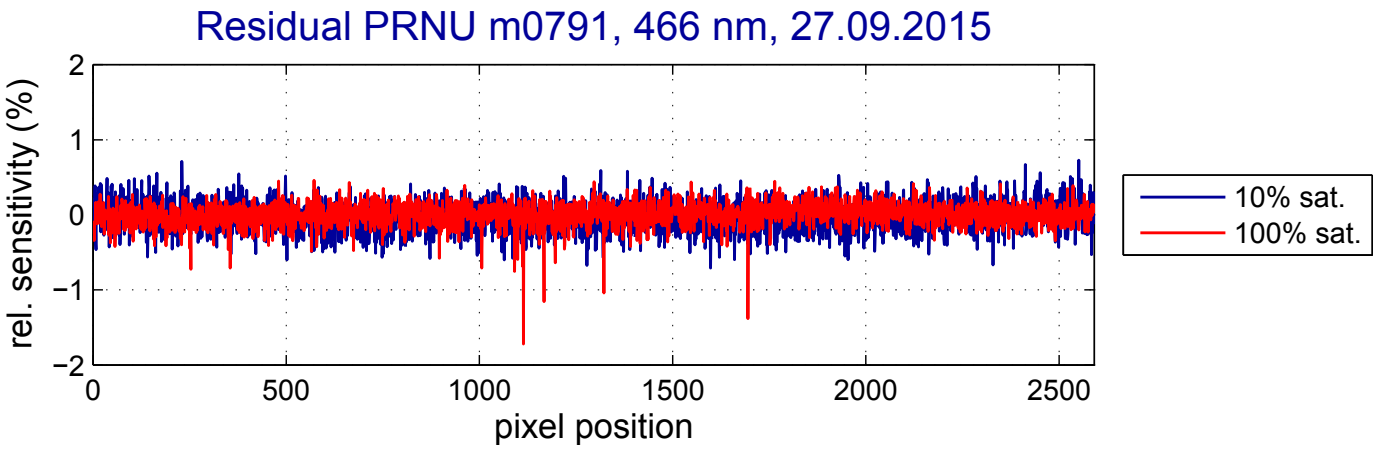


Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise in DN



Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise at 50% saturation in DN

Horizontal profiles residual PRNU (in extension to EMVA 1288)



Horizontal profiles of residual PRNU for middle line in % of mean after two-point calibration with dark image and 50% saturation image for a low and high saturation level.

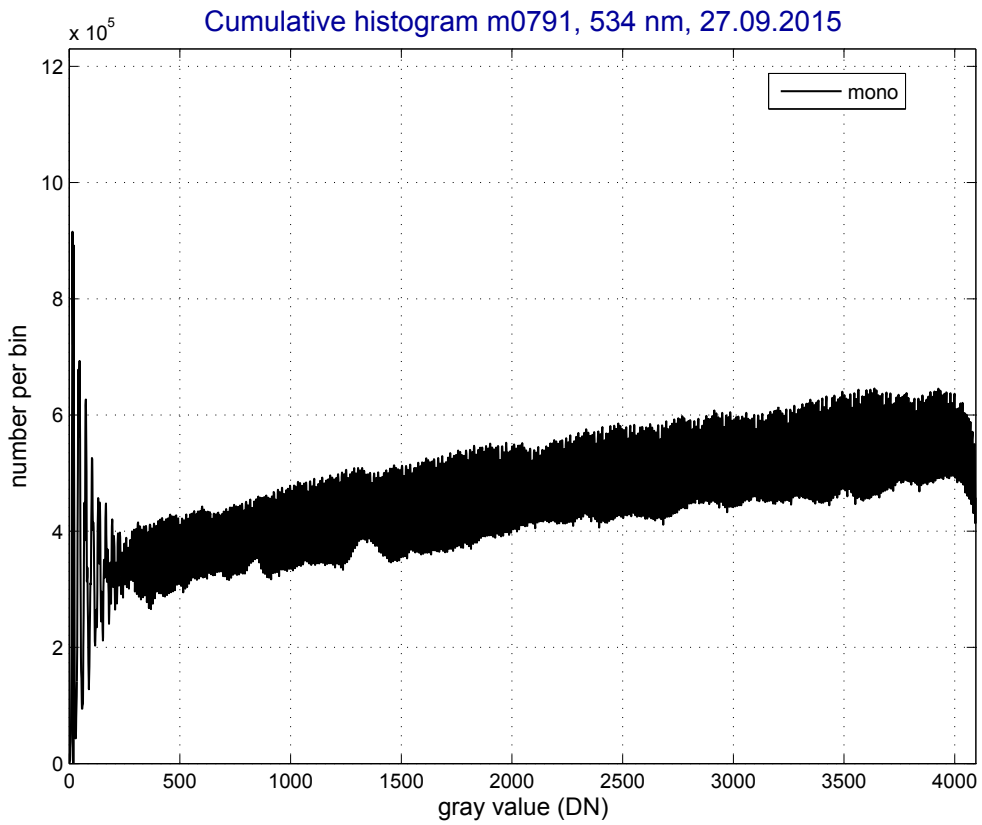
Table with residual inhomogeneities at different saturation levels after a two-point correction with dark image and 50% saturation image.

Saturation %	μ_y DN	σ_y DN	s_y DN	$\sigma_{\text{y.res}}$ DN	$s_{\text{y.corr}}$ DN	$s_{\text{y.corr}}$ %	$s_{\text{y.corr}}/s_y$ %
0	17.33	3.95	1.45	0.17	0.00	0.00	0.00
10	414.97	15.64	7.05	0.69	0.88	0.22	12.51
20	794.67	21.64	13.56	0.96	1.30	0.17	9.61
30	1187.73	26.32	20.37	1.16	1.61	0.14	7.91
40	1575.12	30.25	27.21	1.34	1.86	0.12	6.82
50	1955.37	33.78	33.86	1.49	0.03	0.00	0.10
60	2352.34	36.94	40.67	1.63	2.54	0.11	6.24
70	2742.07	39.67	47.16	1.75	3.05	0.11	6.47
80	3127.10	42.30	54.33	1.87	3.54	0.11	6.51
90	3507.70	44.53	60.52	1.97	4.33	0.12	7.16
100	3904.13	46.22	67.23	2.04	5.91	0.15	8.80

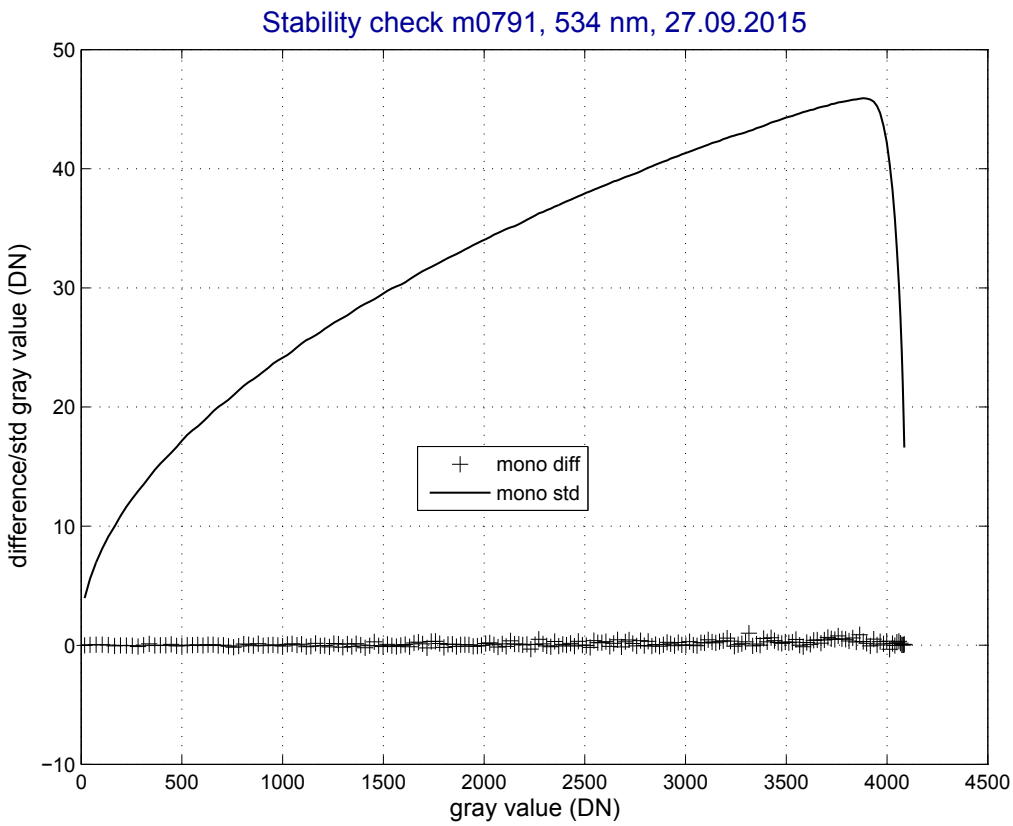
Detailed Data Operating Point 2, 534 nm

Contents

2.1 Checks for Correctness of Measurements and EMVA 1288 Model



Gray value histogram accumulated over all illumination steps (plot in extension of EMVA1288 standard).



Stability check: temporal standard deviation (line) and difference of mean of two images (crosses) for all illumination steps (plot in extension of EMVA1288 standard).

Covariance coefficients of neighboring pixels averaged over the whole image sensor. Values unequal zero except for coefficient without shift, which is one, indicate some kind of preprocessing. This makes the central assumption of the linear EMVA 1288 model invalid. The gain K will then be lower and the quantum efficiency η higher than the true values.

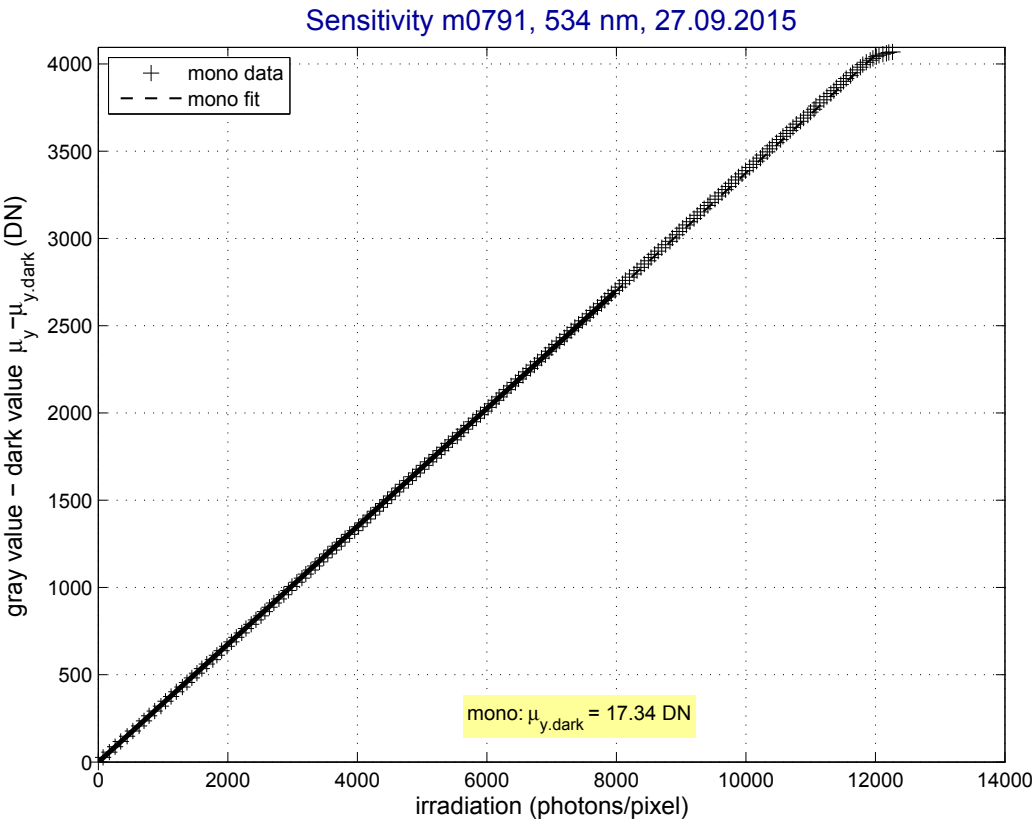
List of covariance coefficients in 9×9 neighborhood, dark image (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.002	0.019	0.001	0.039	0.000	0.025	0.000	0.040
0.005	0.000	0.005	0.002	0.004	0.002	0.005	0.000	0.004
0.002	0.000	0.004	0.000	0.006	0.000	0.007	0.001	0.008
0.005	0.002	0.005	0.000	0.005	0.001	0.005	0.000	0.006
0.008	0.000	0.004	0.000	0.006	0.000	0.004	0.000	0.003
0.006	0.001	0.004	0.002	0.005	0.001	0.002	0.000	0.006
0.003	0.001	0.004	0.001	0.005	0.002	0.005	0.002	0.007
0.006	0.001	0.004	0.002	0.006	0.001	0.005	0.001	0.005
0.007	0.001	0.006	0.000	0.005	0.001	0.005	0.000	0.002

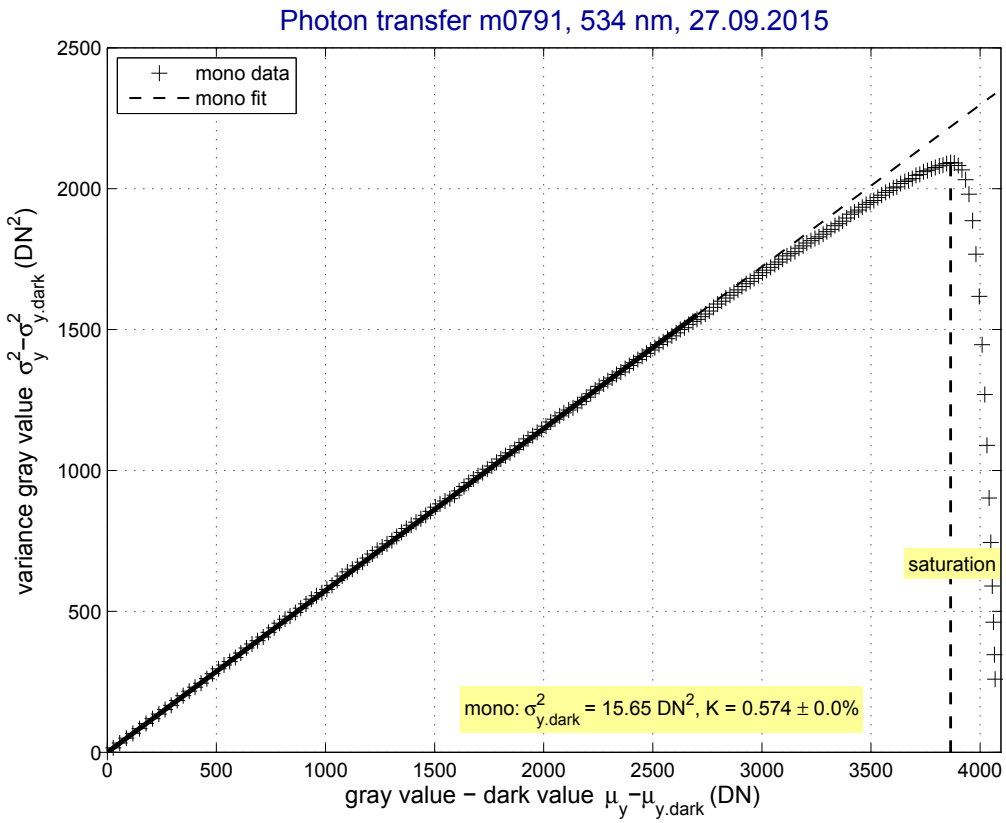
List of covariance coefficients in 9×9 neighborhood, 70% saturation (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.007	0.033	0.000	0.005	0.000	0.000	0.000	0.003
0.002	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.000
0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.001
0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001
0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.000
0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000

2.2 Sensitivity and Noise

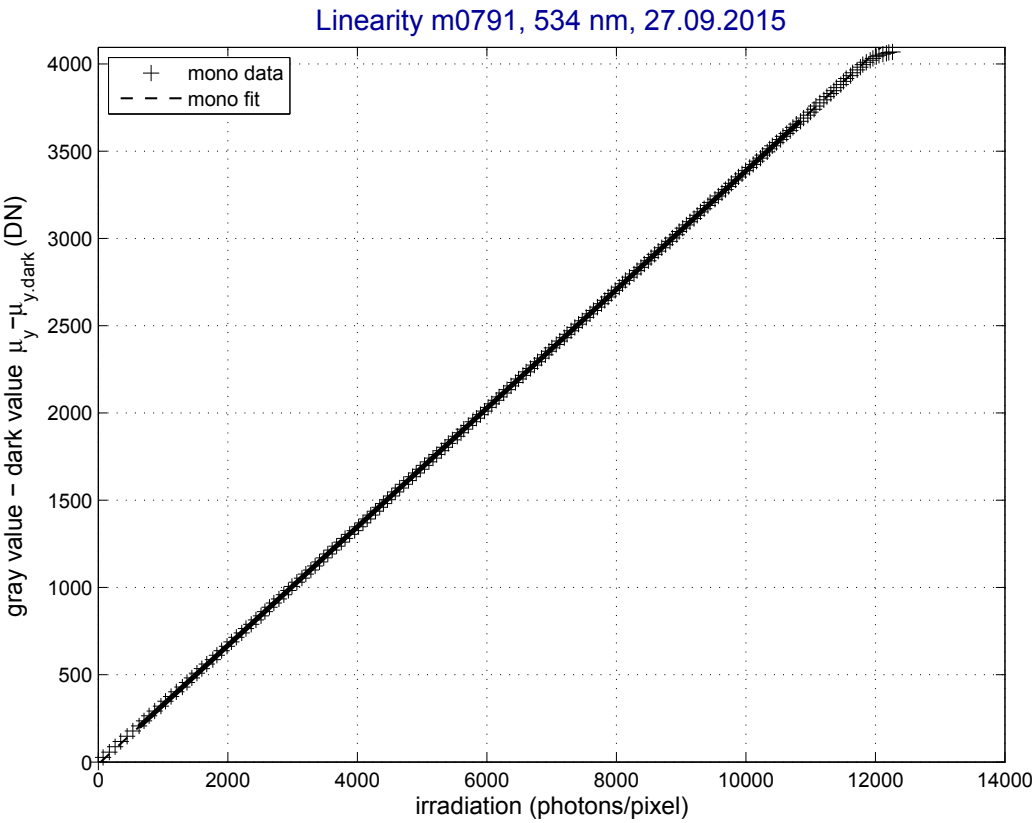


Characteristics camera curve (sensitivity plot) with 201 illumination steps.

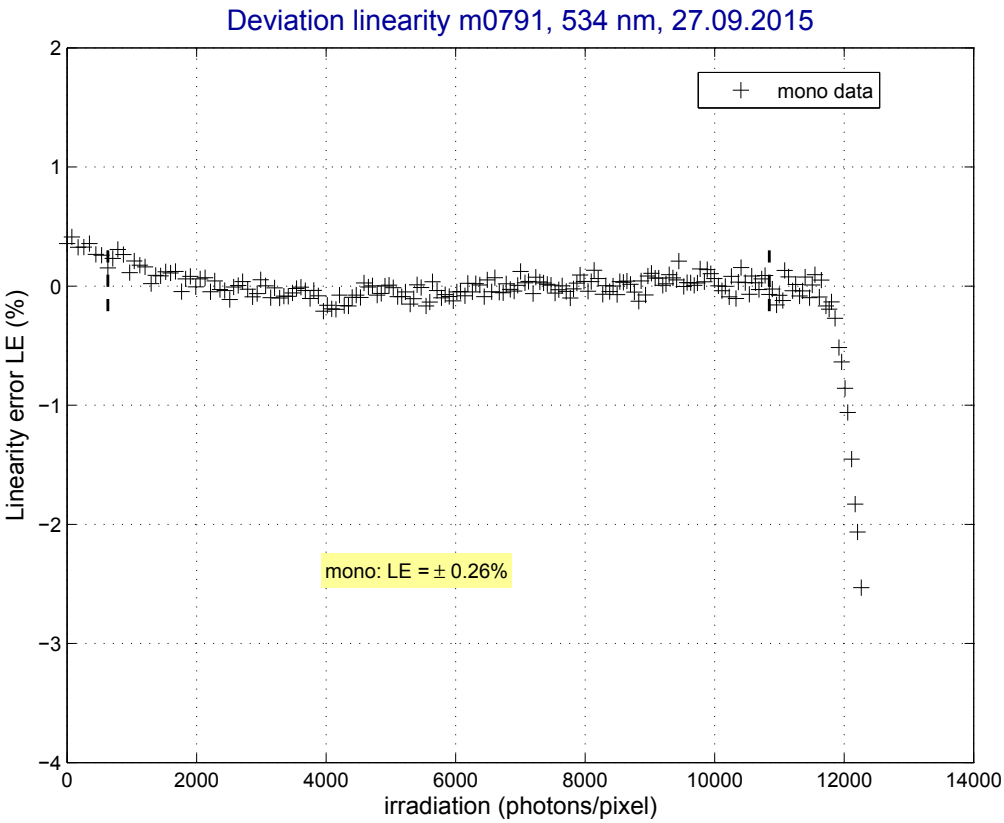


Photon transfer curve with 201 illumination steps.

2.3 Linearity

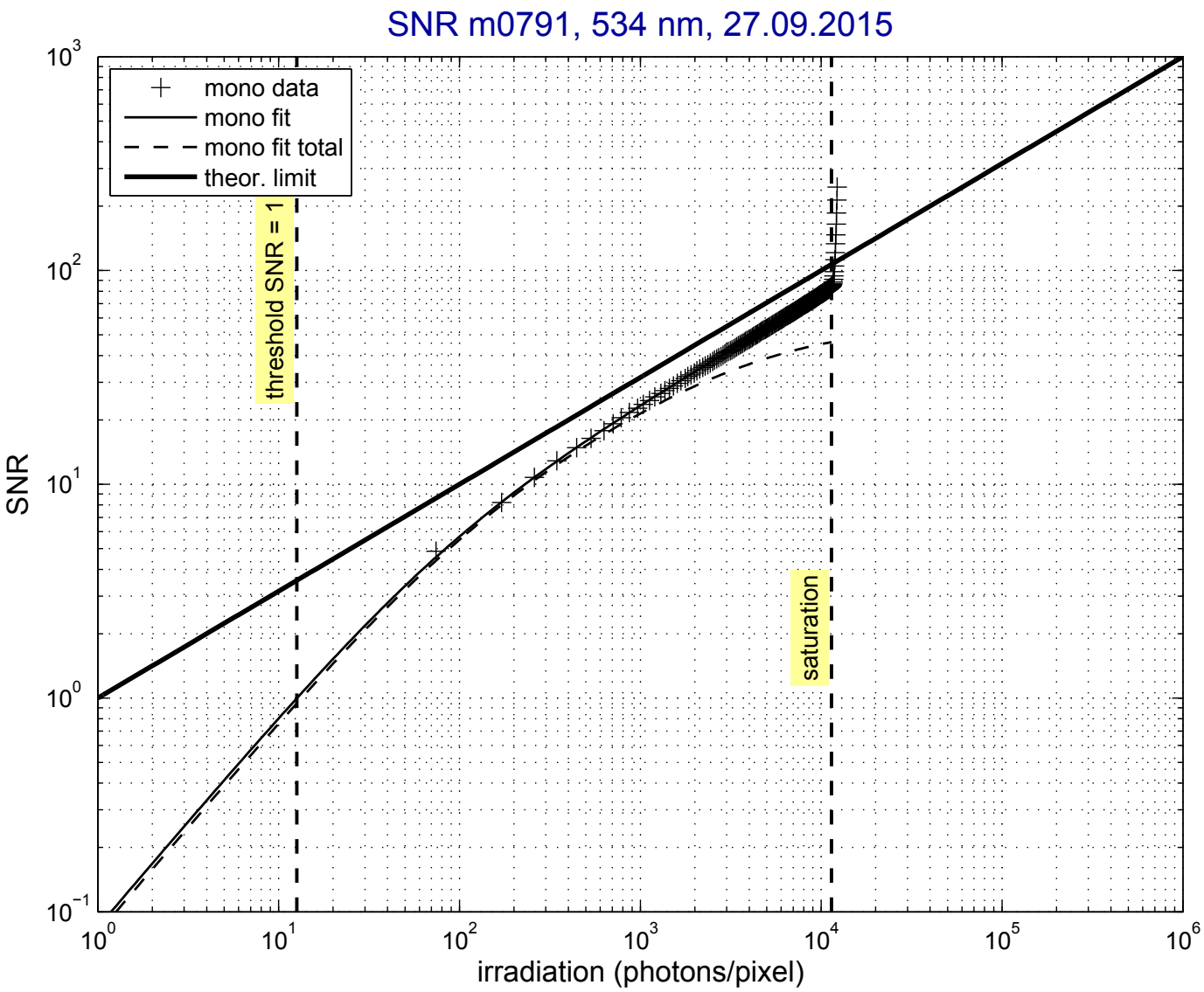


Linearity curve.



Deviation from linearity.

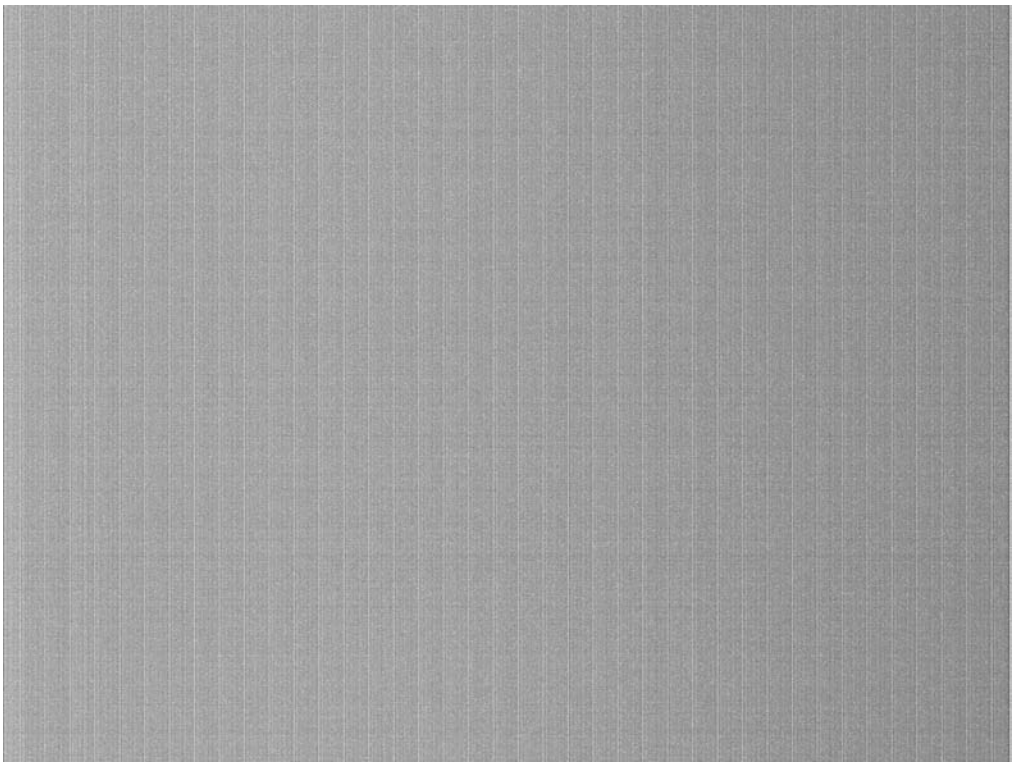
2.4 Signal-to-Noise Ratio (SNR)



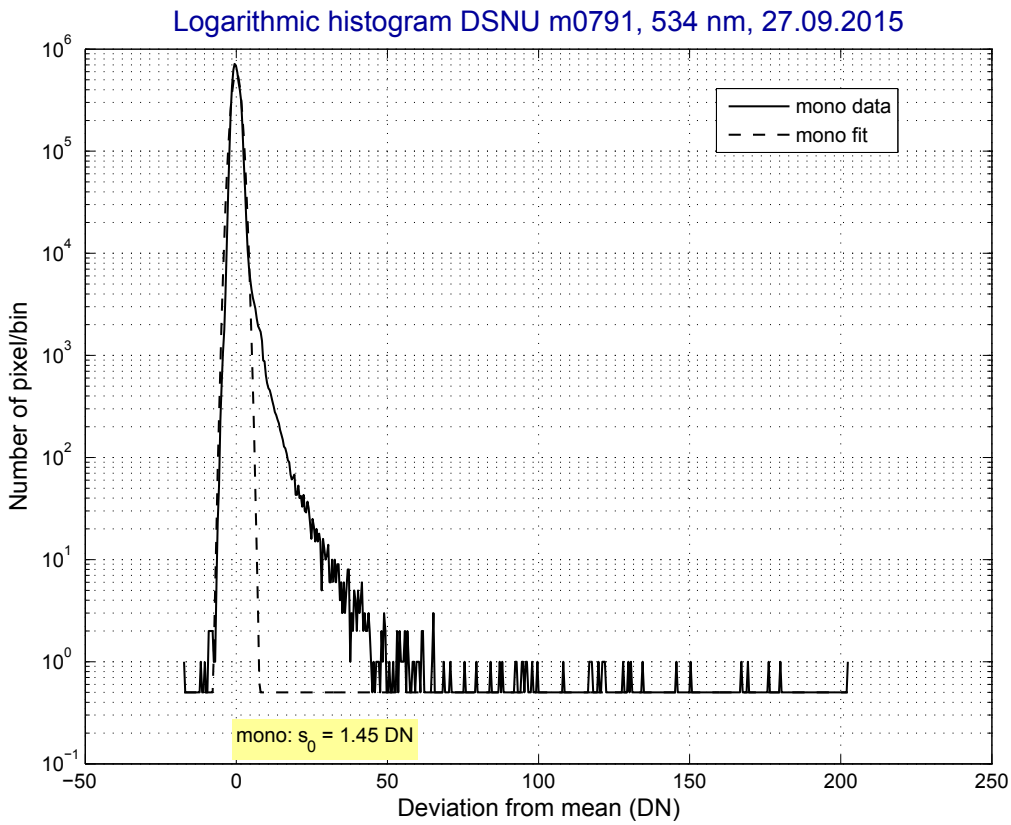
Signal-to-noise ratio in double-logarithmic presentation.

2.5 Nonuniformity: DSNU, PRNU, profiles, spectograms

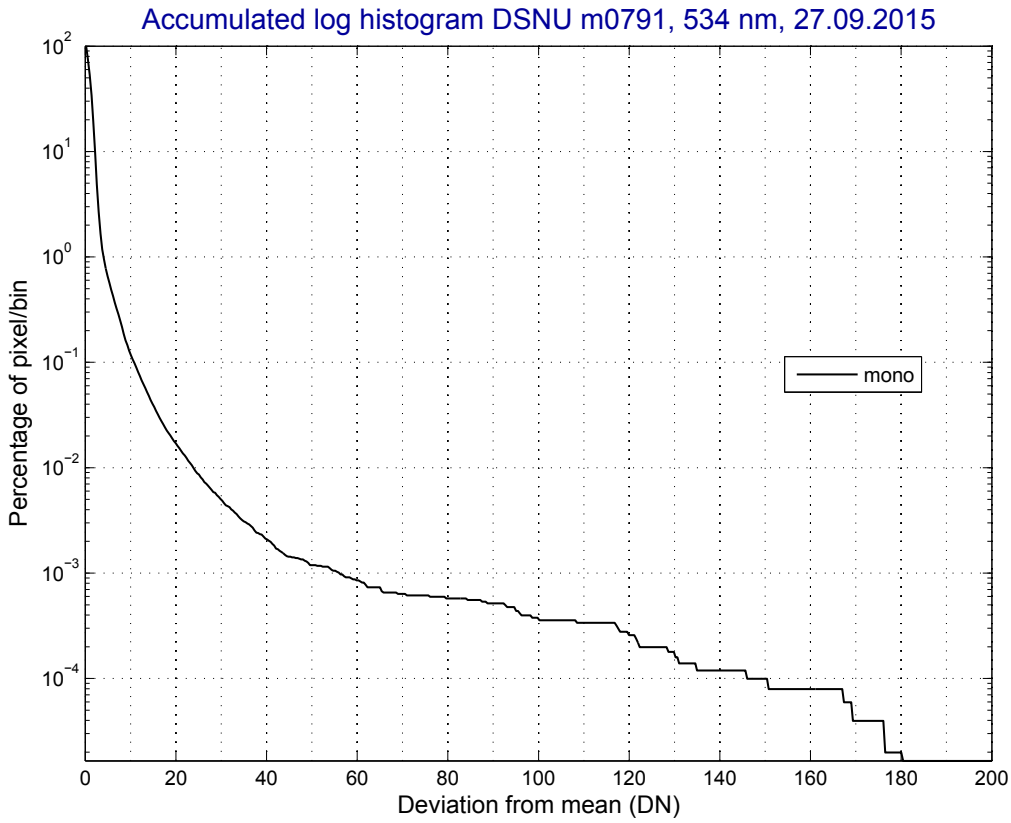
DSNU



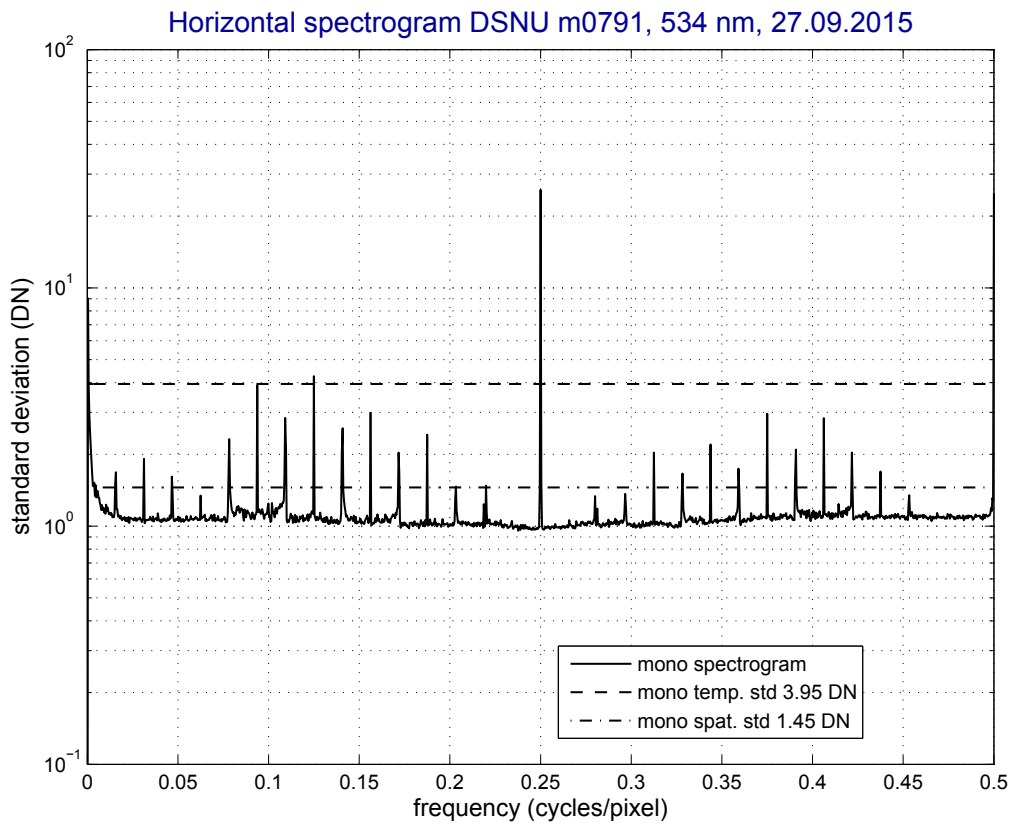
Contrast enhanced dark image, range 13.0 - 21.7 DN (not part of EMVA 1288 standard).



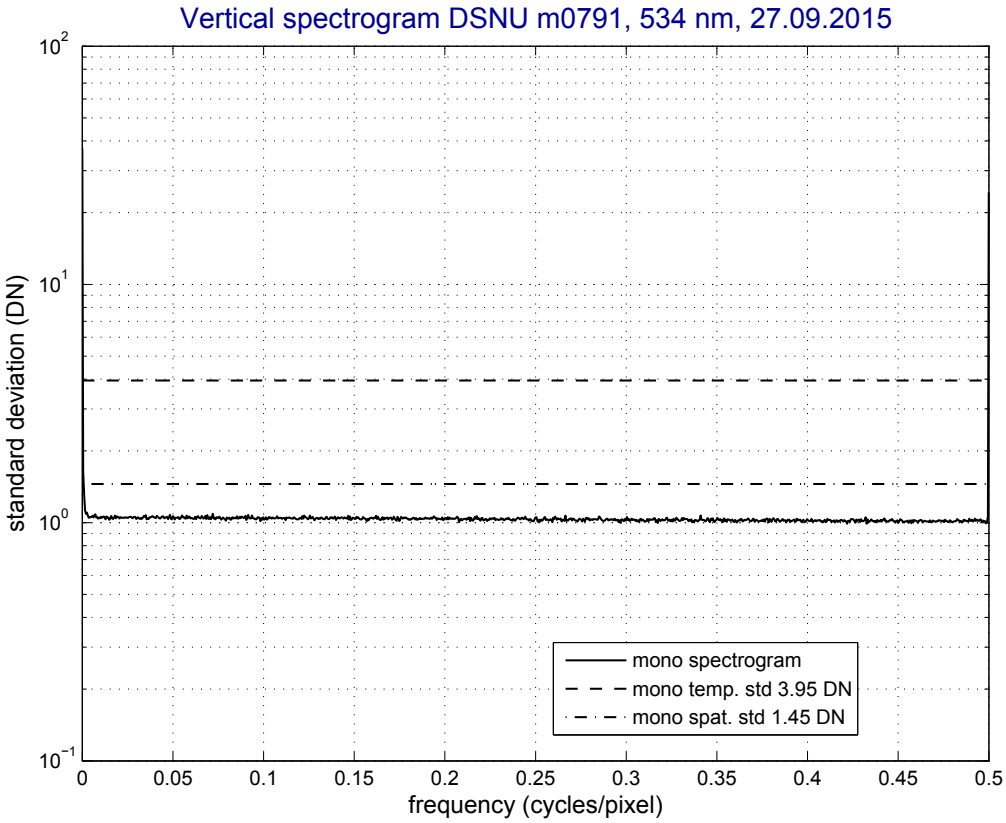
Logarithmic histogram of spatial deviation from mean in units DN.



Accumumulated logarithmic histogram of absolute spatial deviation from mean in units DN.

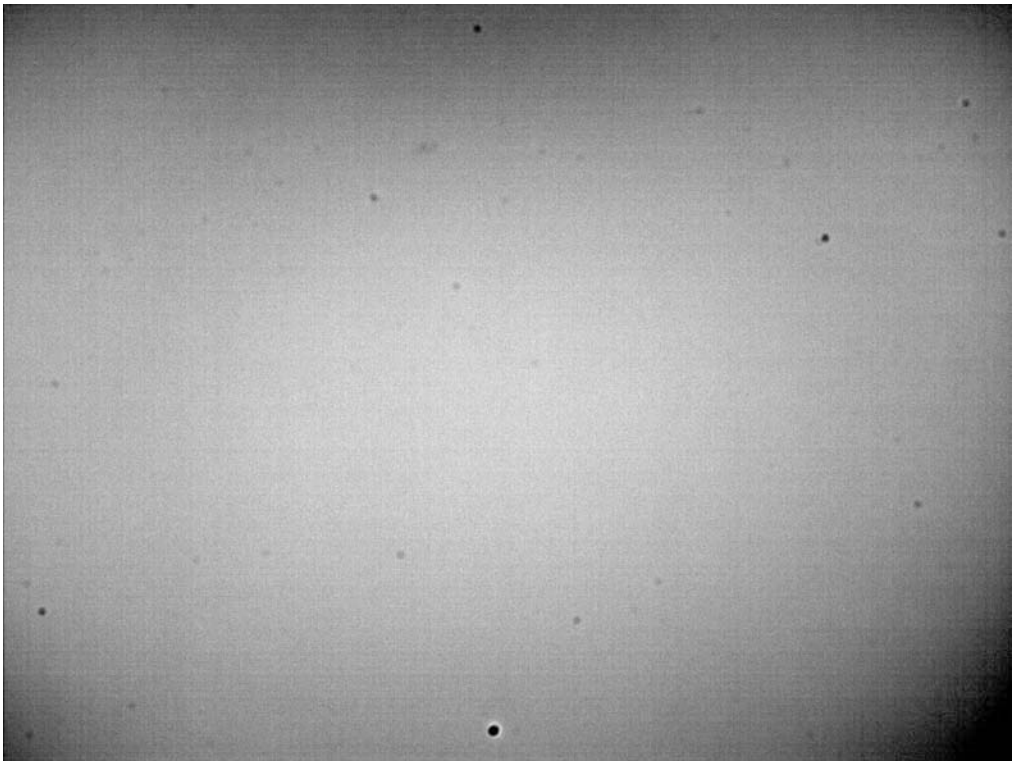


Horizontal spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

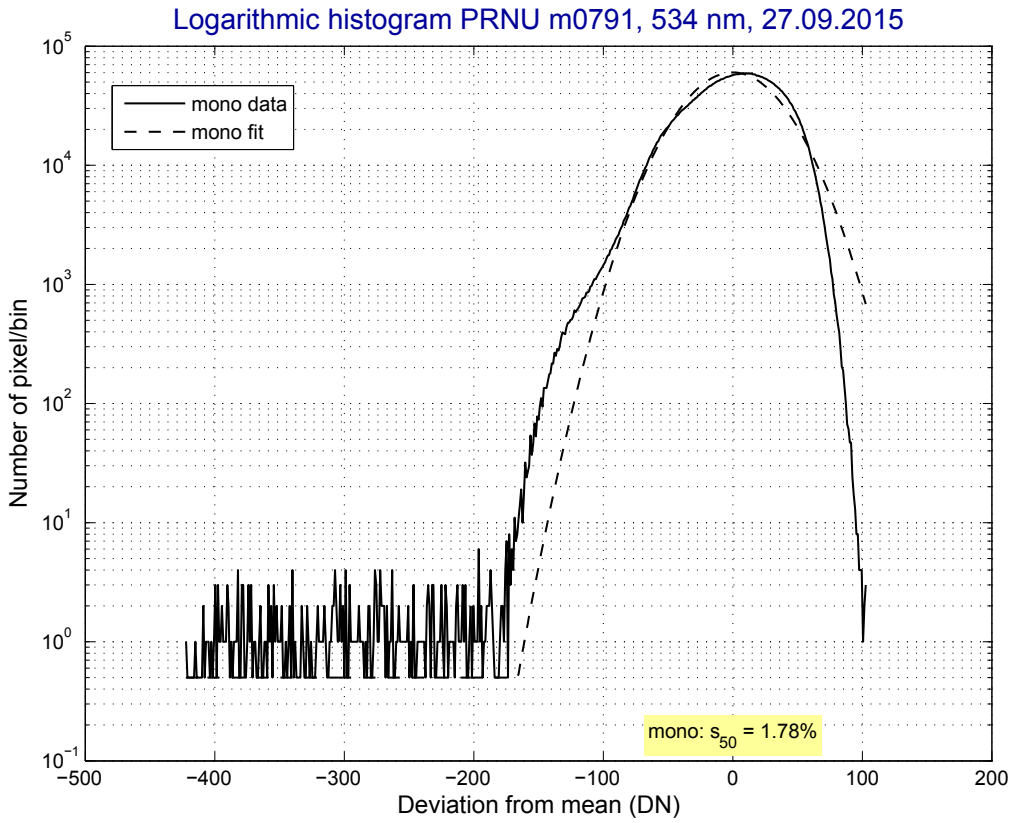


Vertical spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

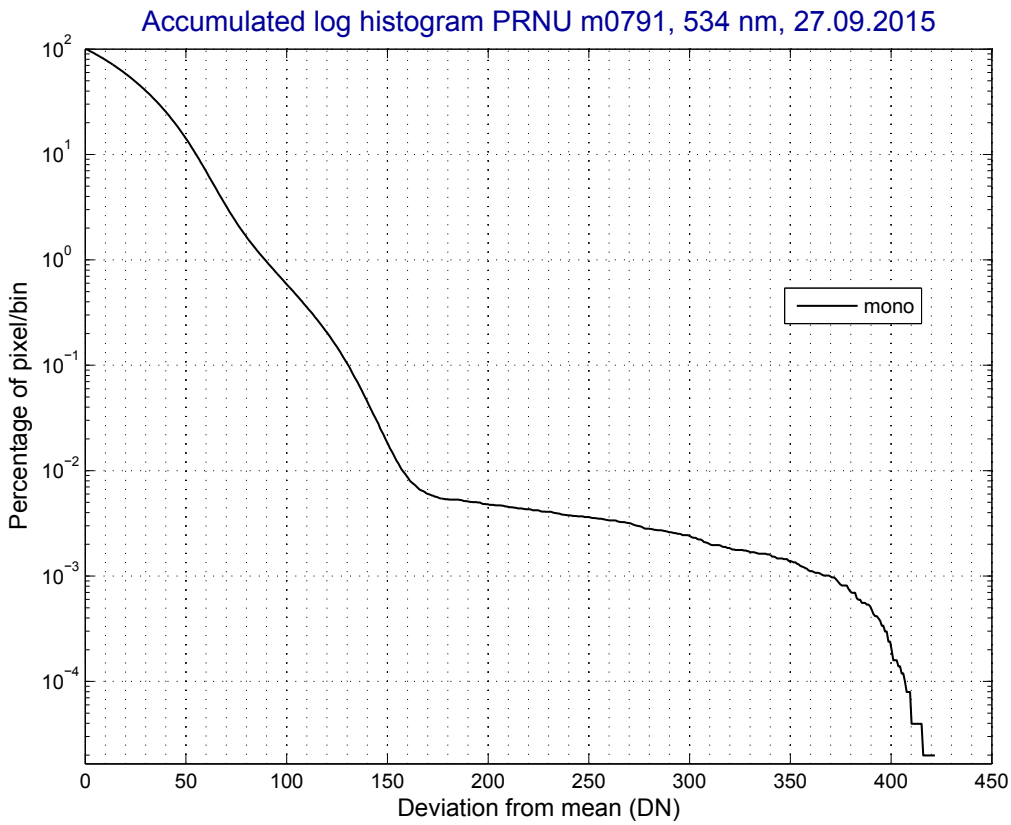
PRNU



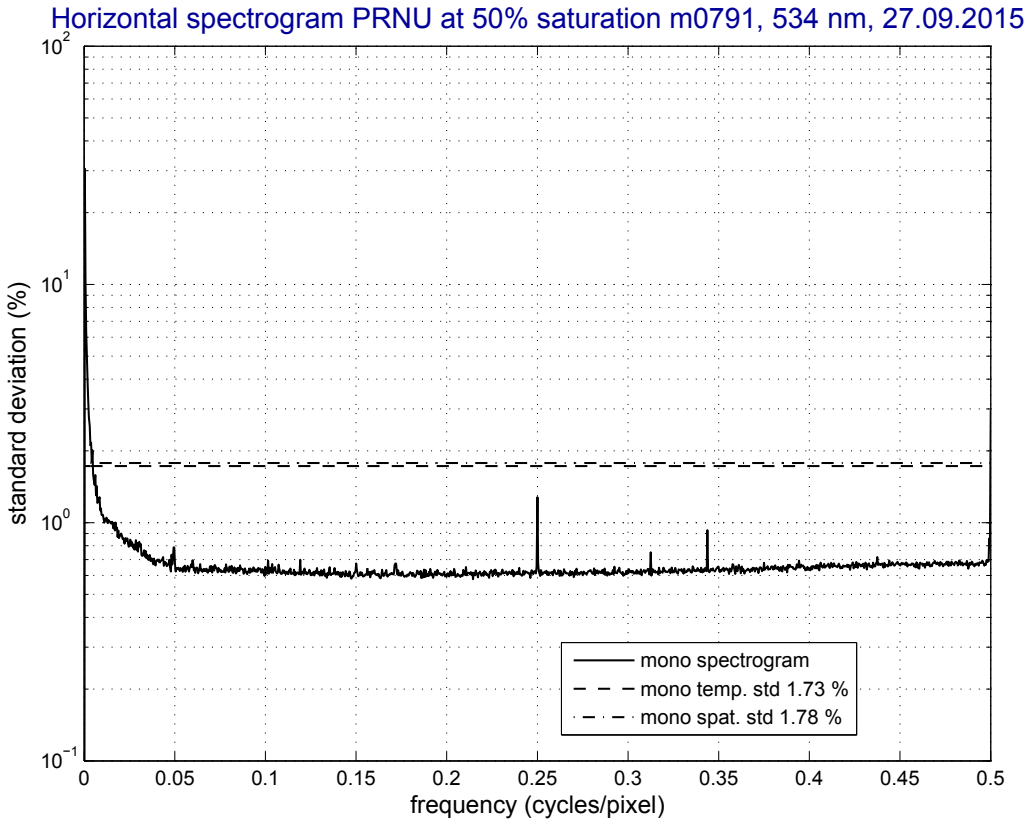
Contrast enhanced response image, range ±5.3% (not part of EMVA 1288 standard).



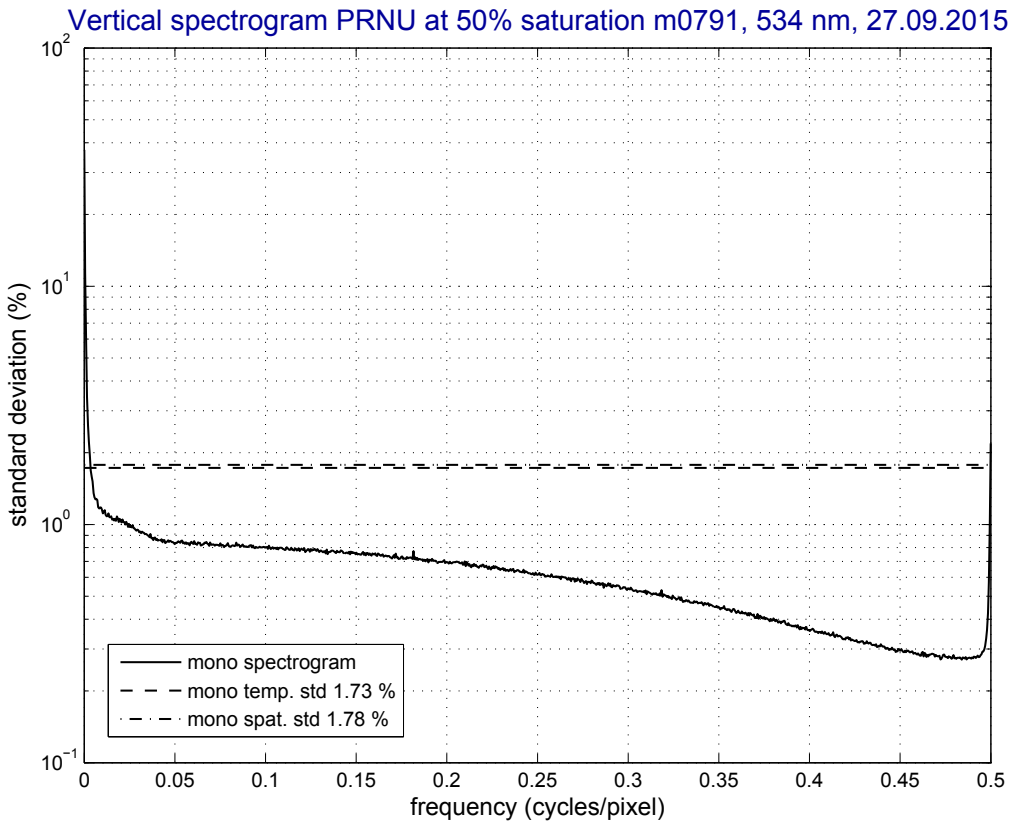
Logarithmic histogram of spatial deviation from mean in units %



Accumulated logarithmic histogram of absolute spatial deviation from mean in units %

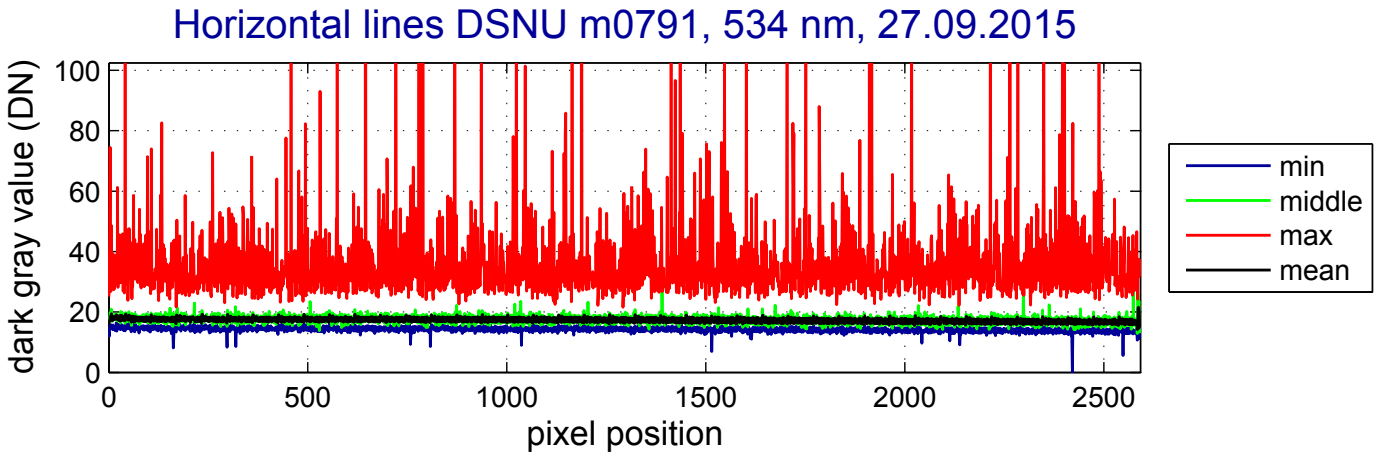


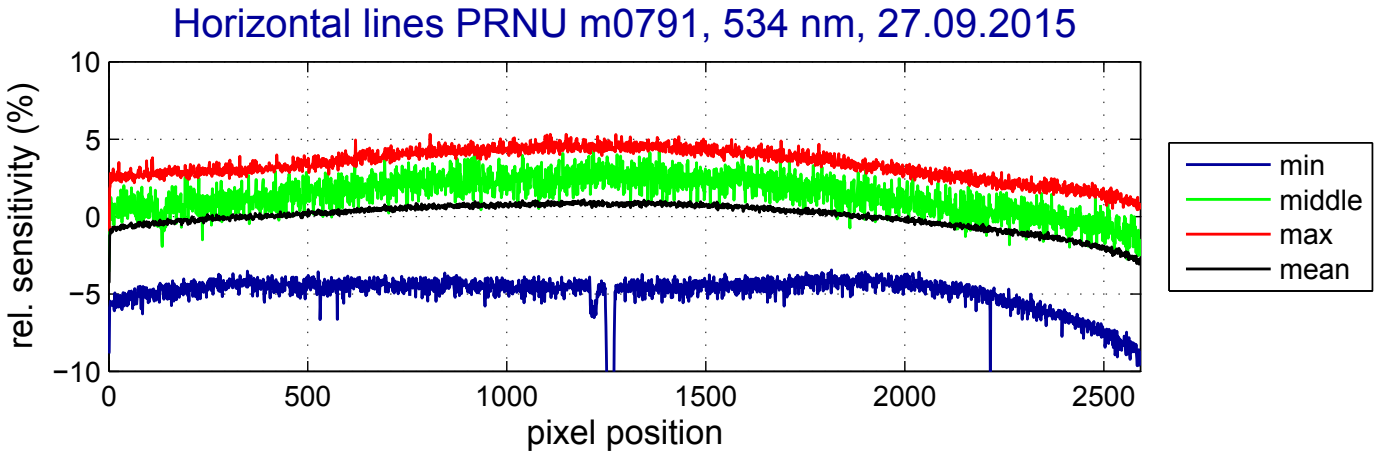
Horizontal spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.076%.



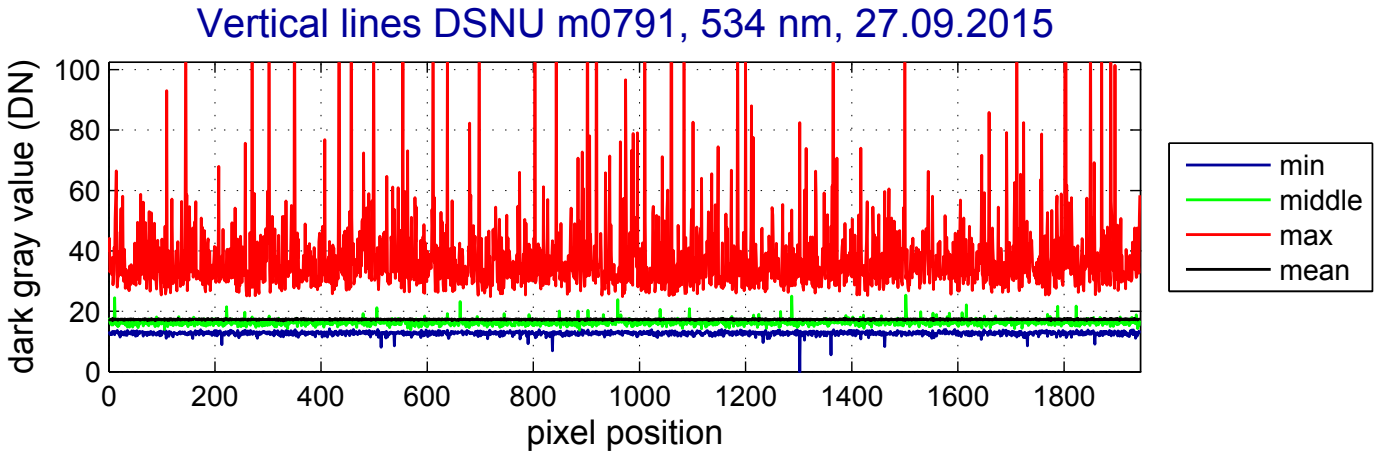
Vertical spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.076%.

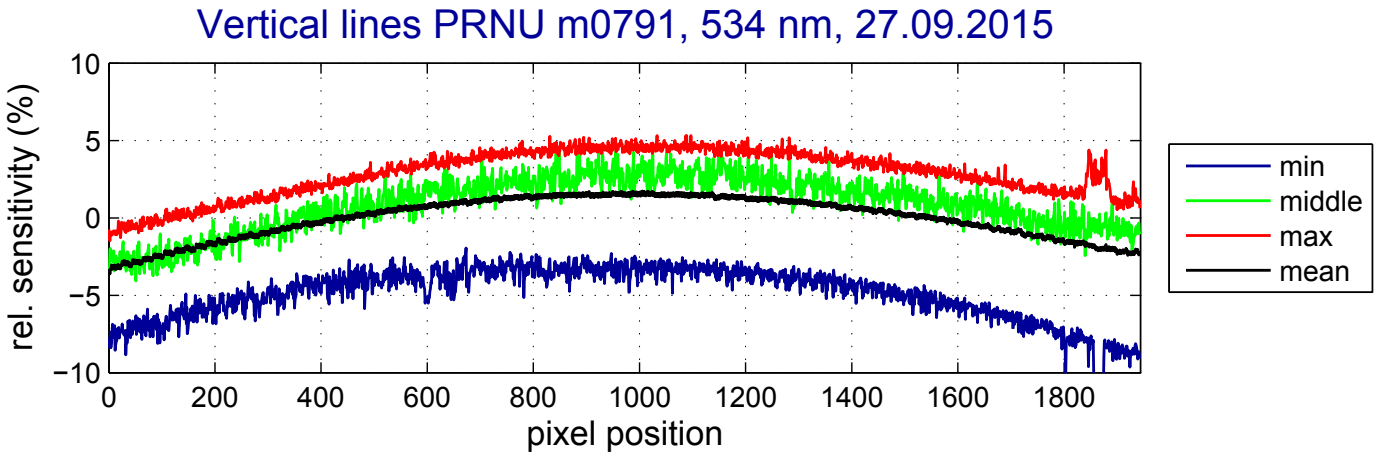
Horizontal and vertical profiles (preliminary, release 3.1)





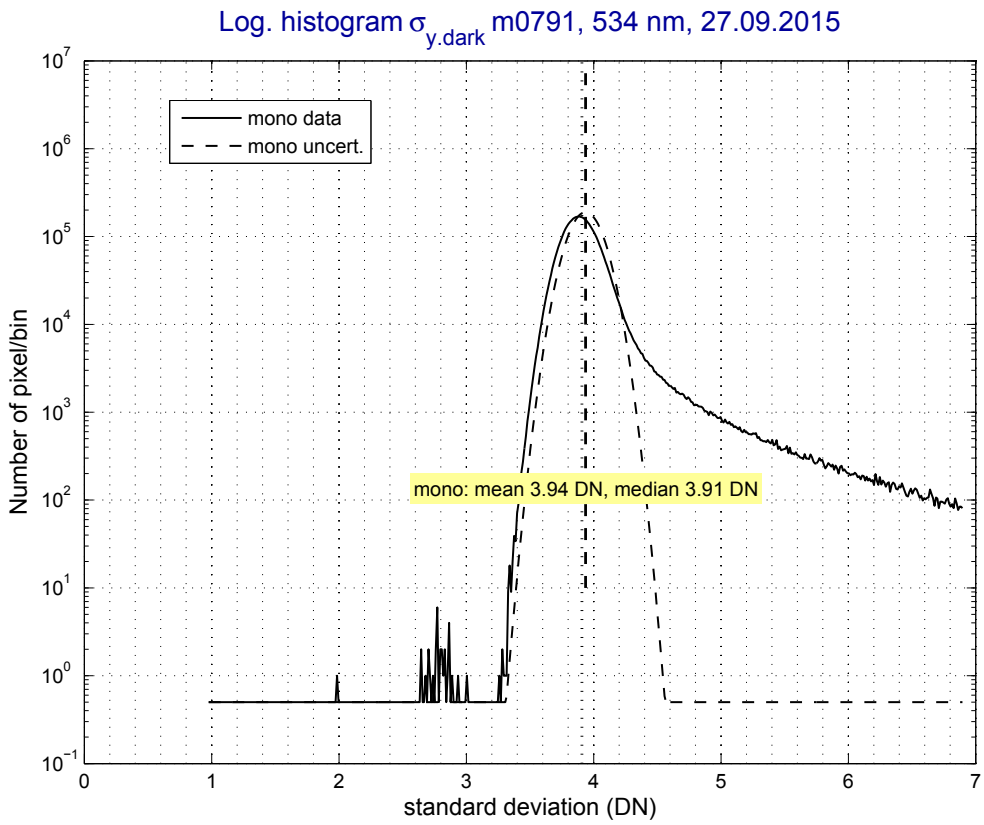
Horizontal profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.



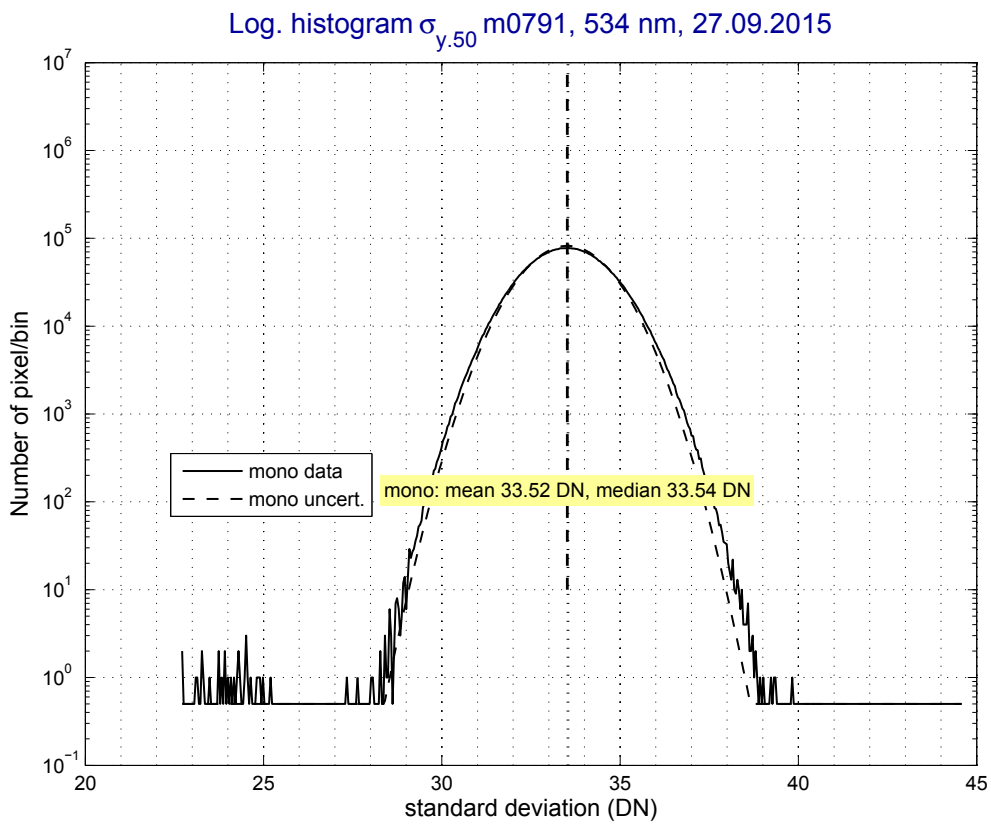


Vertical profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.

Spatial variation of temporal noise (extension to EMVA 1288)

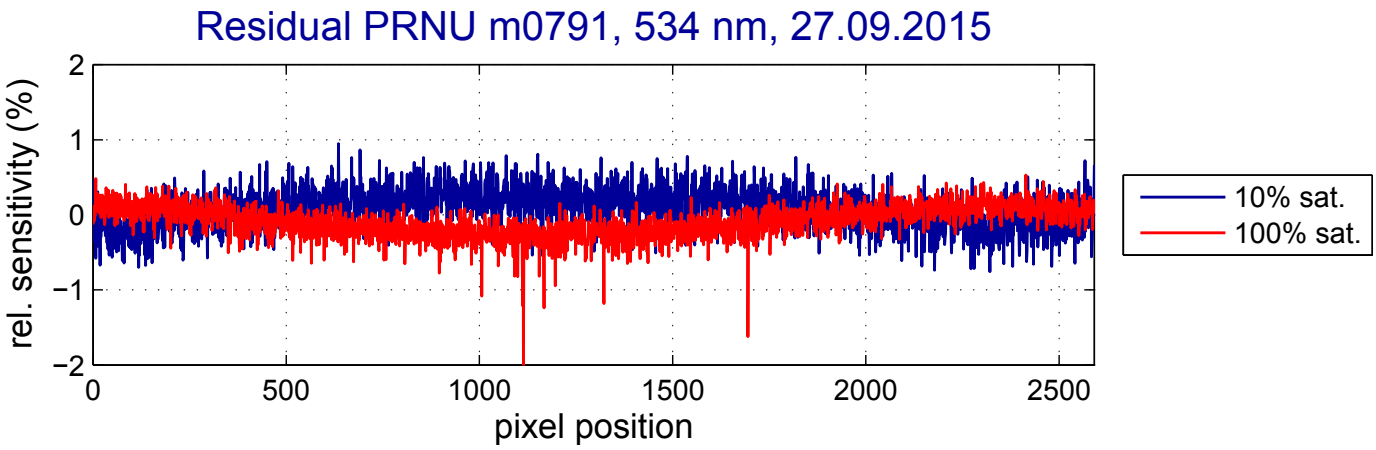


Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise in DN



Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise at 50% saturation in DN

Horizontal profiles residual PRNU (in extension to EMVA 1288)



Horizontal profiles of residual PRNU for middle line in % of mean after two-point calibration with dark image and 50% saturation image for a low and high saturation level.

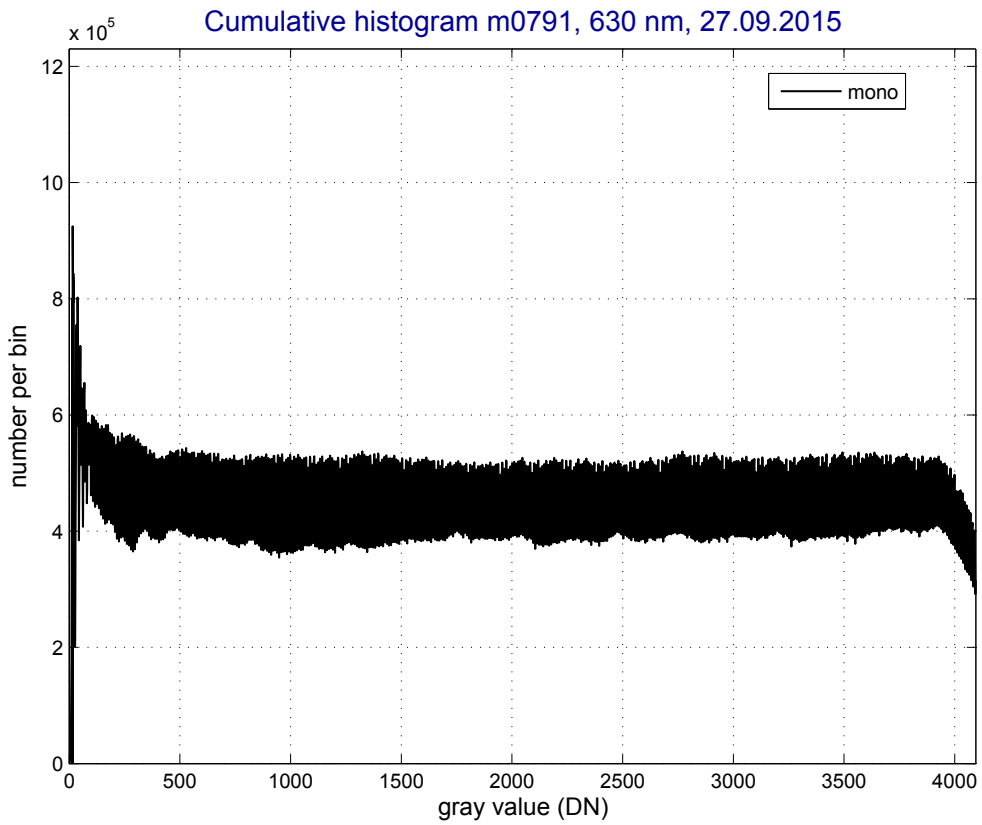
Table with residual inhomogeneities at different saturation levels after a two-point correction with dark image and 50% saturation image.

Saturation %	μ_y DN	σ_y DN	s_y DN	$\sigma_{\text{y.res}}$ DN	$s_{\text{y.corr}}$ DN	$s_{\text{y.corr}}$ %	$s_{\text{y.corr}}/s_y$ %
0	17.33	3.95	1.45	0.17	0.00	0.00	0.00
10	392.78	15.25	7.21	0.67	1.03	0.27	14.24
20	781.57	21.38	14.13	0.95	1.47	0.19	10.39
30	1162.65	26.01	20.82	1.15	1.74	0.15	8.33
40	1541.19	29.93	27.45	1.32	1.92	0.12	6.98
50	1944.71	33.57	34.37	1.48	0.01	0.00	0.04
60	2329.06	36.64	40.66	1.62	2.61	0.11	6.41
70	2717.71	39.37	46.96	1.74	3.42	0.13	7.29
80	3110.94	42.00	53.76	1.86	4.08	0.13	7.59
90	3492.76	44.23	59.44	1.95	5.38	0.15	9.05
100	3880.00	45.90	65.48	2.03	7.48	0.19	11.43

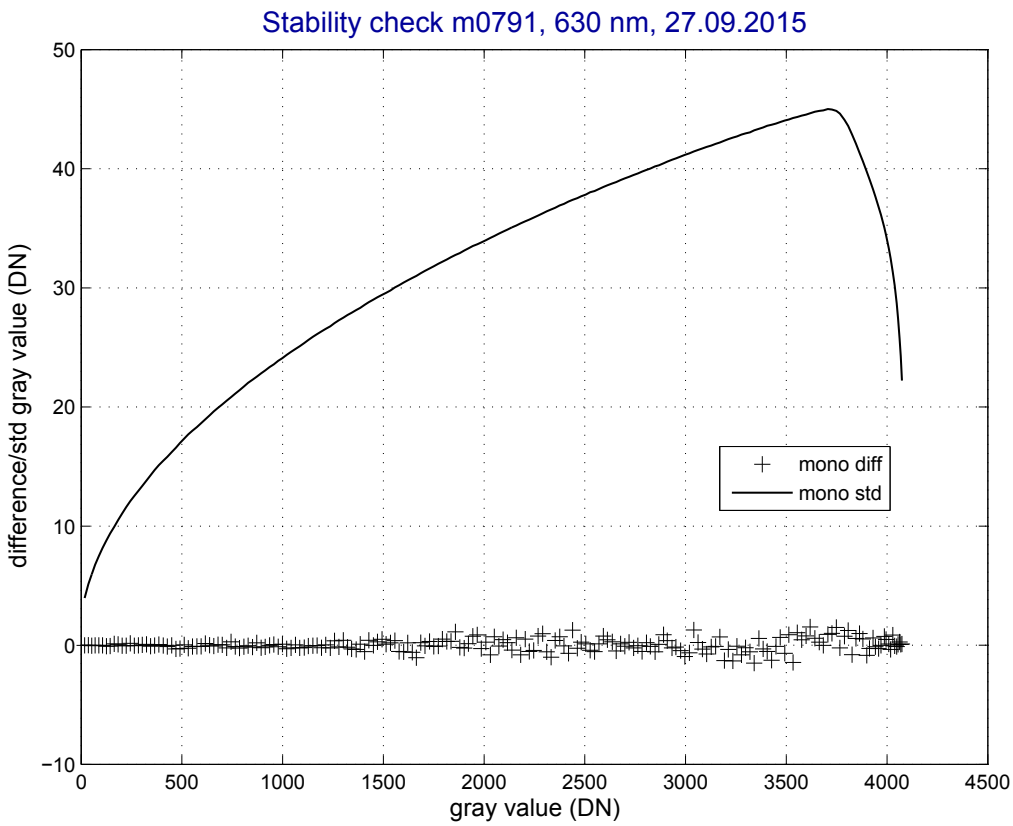
Detailed Data Operating Point 3, 630 nm

Contents

3.1 Checks for Correctness of Measurements and EMVA 1288 Model



Gray value histogram accumulated over all illumination steps (plot in extension of EMVA1288 standard).



Stability check: temporal standard deviation (line) and difference of mean of two images (crosses) for all illumination steps (plot in extension of EMVA1288 standard).

Covariance coefficients of neighboring pixels averaged over the whole image sensor. Values unequal zero except for coefficient without shift, which is one, indicate some kind of preprocessing. This makes the central assumption of the linear EMVA 1288 model invalid. The gain K will then be lower and the quantum efficiency η higher than the true values.

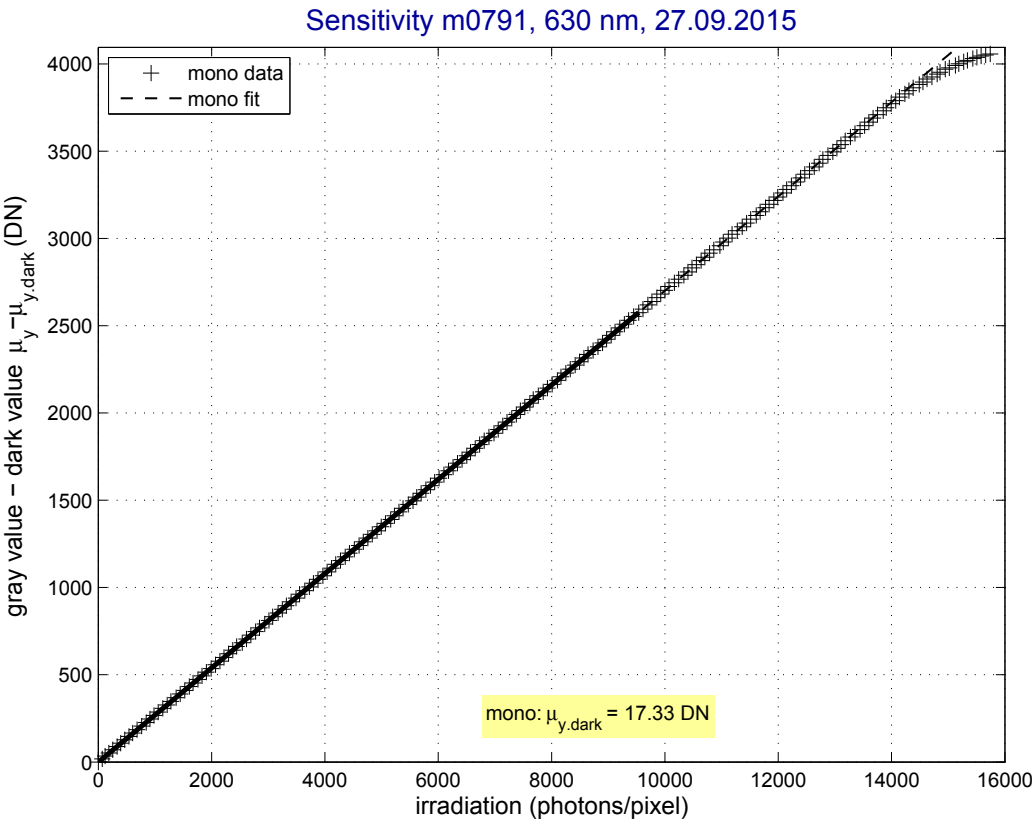
List of covariance coefficients in 9×9 neighborhood, dark image (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.001	0.019	0.001	0.041	0.001	0.025	0.001	0.041
0.001	0.000	0.002	0.002	0.000	0.001	0.001	0.001	0.001
0.002	0.002	0.006	0.001	0.004	0.002	0.007	0.002	0.008
0.002	0.001	0.001	0.001	0.003	0.001	0.000	0.000	0.001
0.007	0.000	0.006	0.000	0.005	0.000	0.004	0.000	0.003
0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002
0.004	0.000	0.003	0.000	0.006	0.000	0.005	0.000	0.008
0.000	0.000	0.003	0.002	0.001	0.001	0.002	0.000	0.000
0.007	0.000	0.007	0.000	0.005	0.000	0.005	0.000	0.003

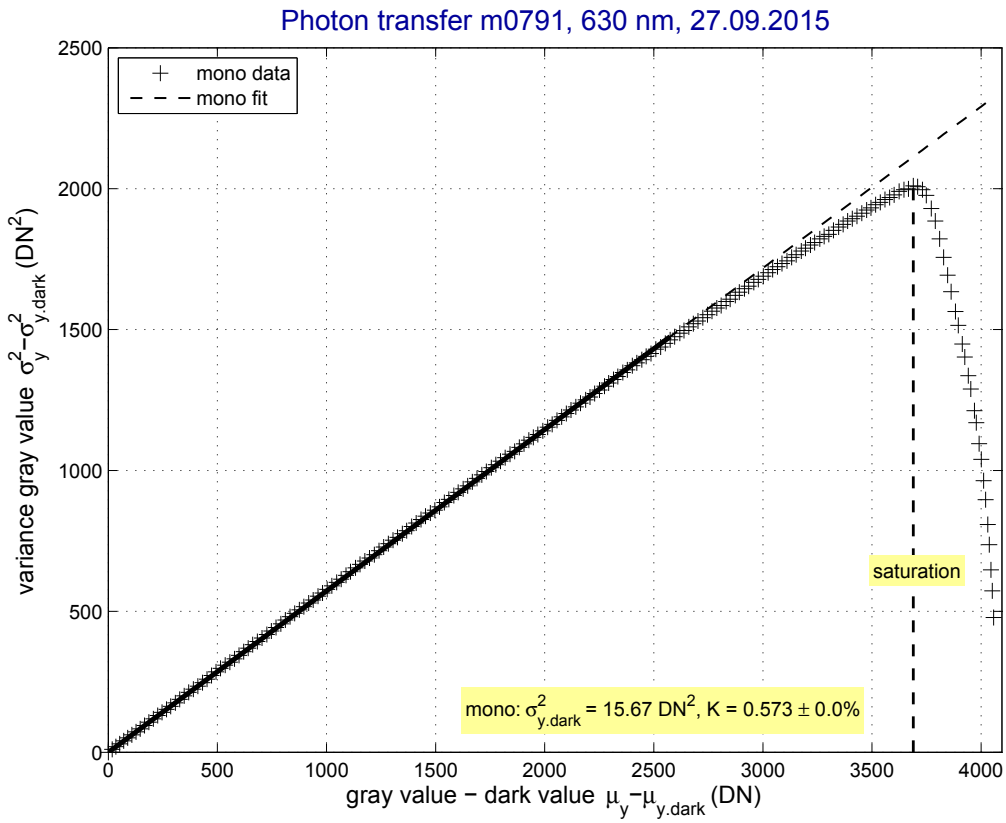
List of covariance coefficients in 9×9 neighborhood, 70% saturation (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.006	0.032	0.000	0.004	0.000	0.000	0.000	0.001
0.003	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.000
0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000
0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
0.000	0.000	0.001	0.000	0.001	0.002	0.000	0.000	0.001
0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

3.2 Sensitivity and Noise

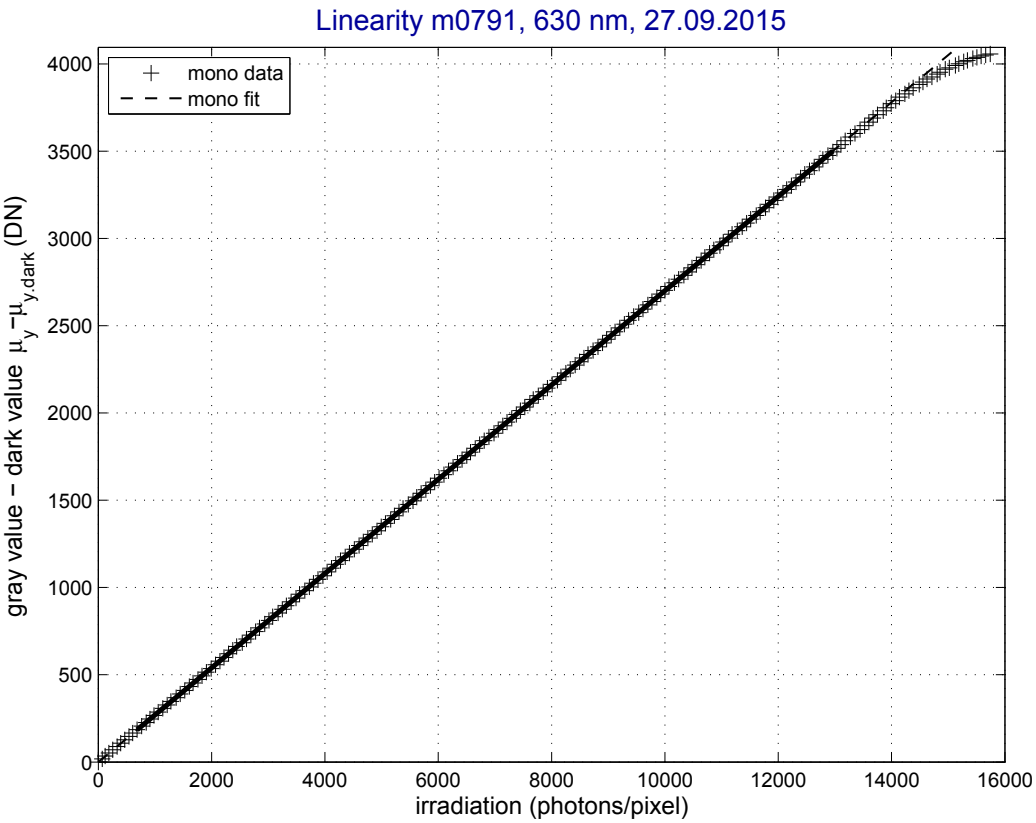


Characteristics camera curve (sensitivity plot) with 201 illumination steps.

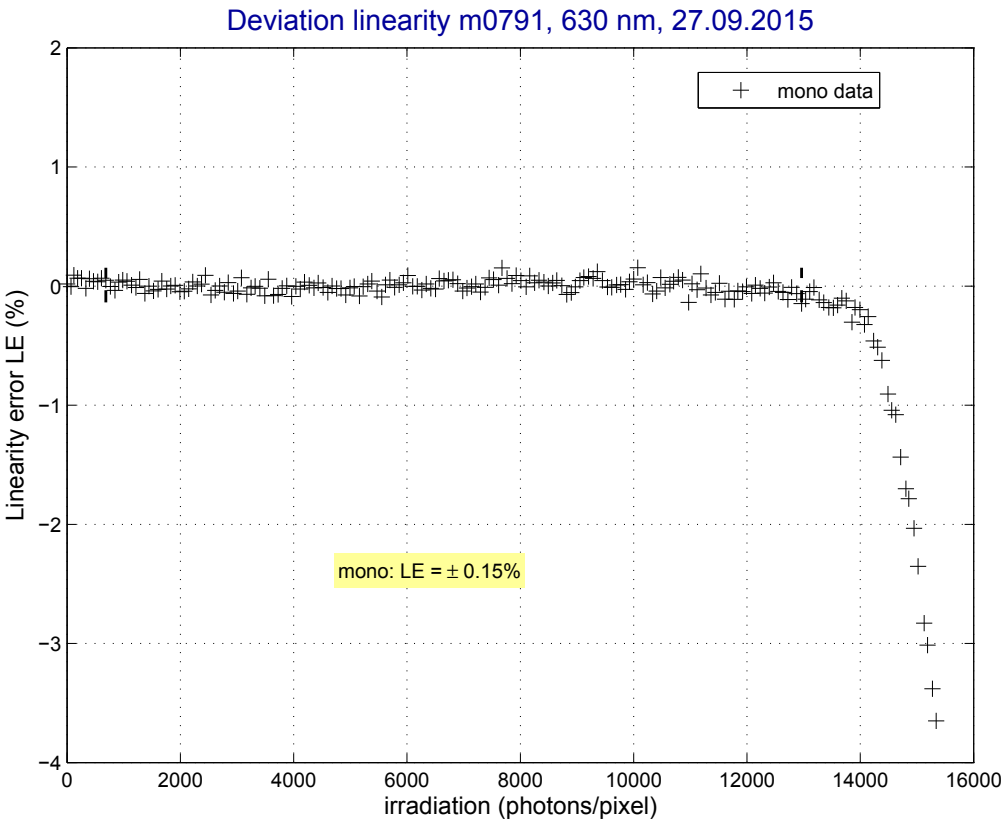


Photon transfer curve with 201 illumination steps.

3.3 Linearity

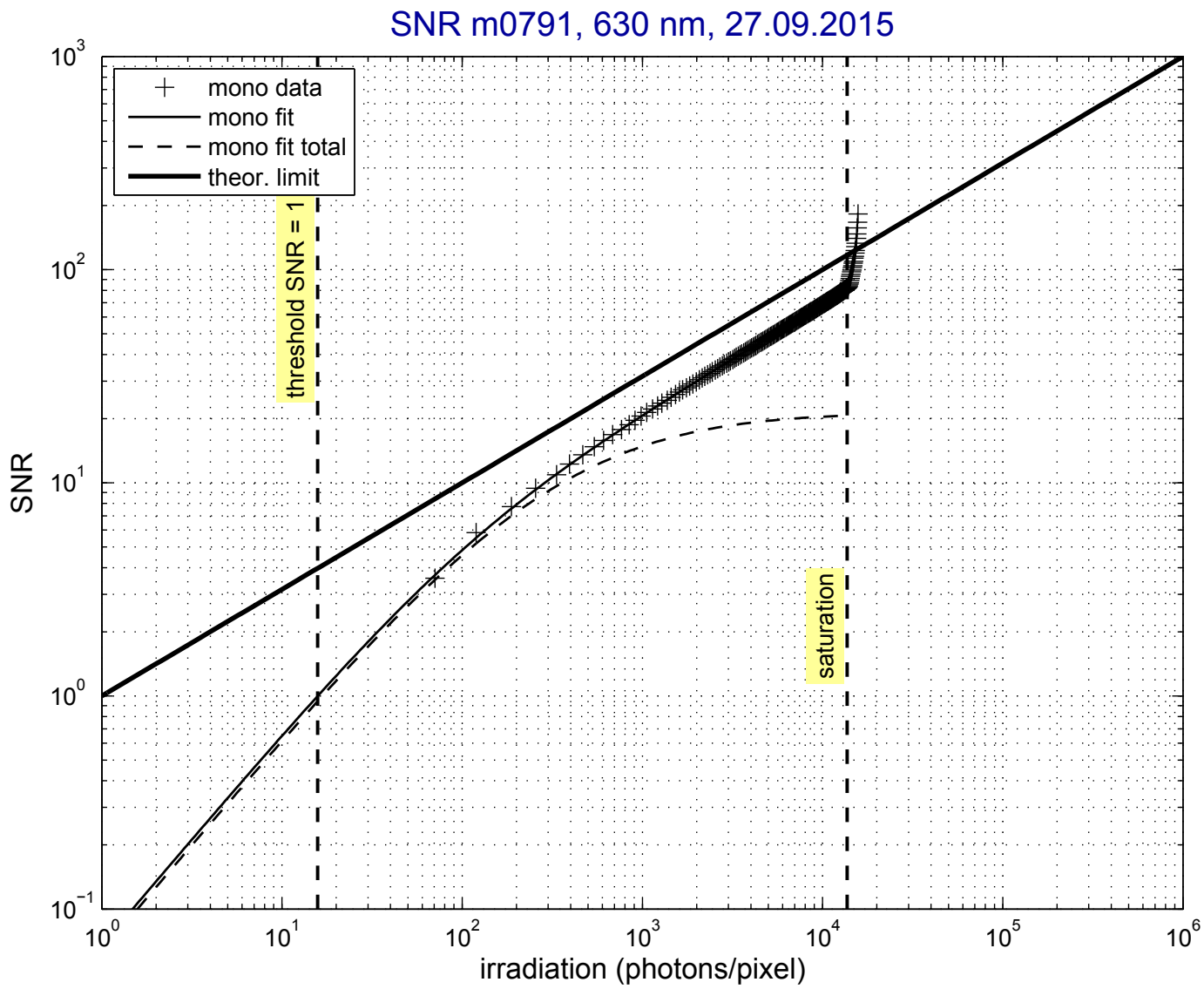


Linearity curve.



Deviation from linearity.

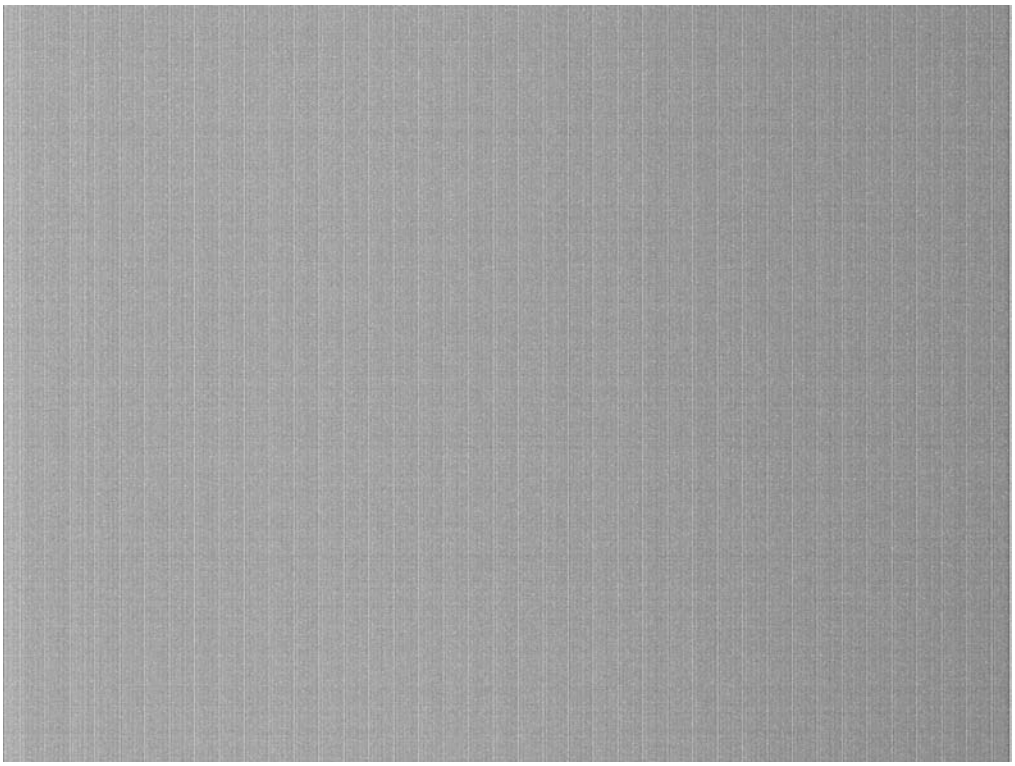
3.4 Signal-to-Noise Ratio (SNR)



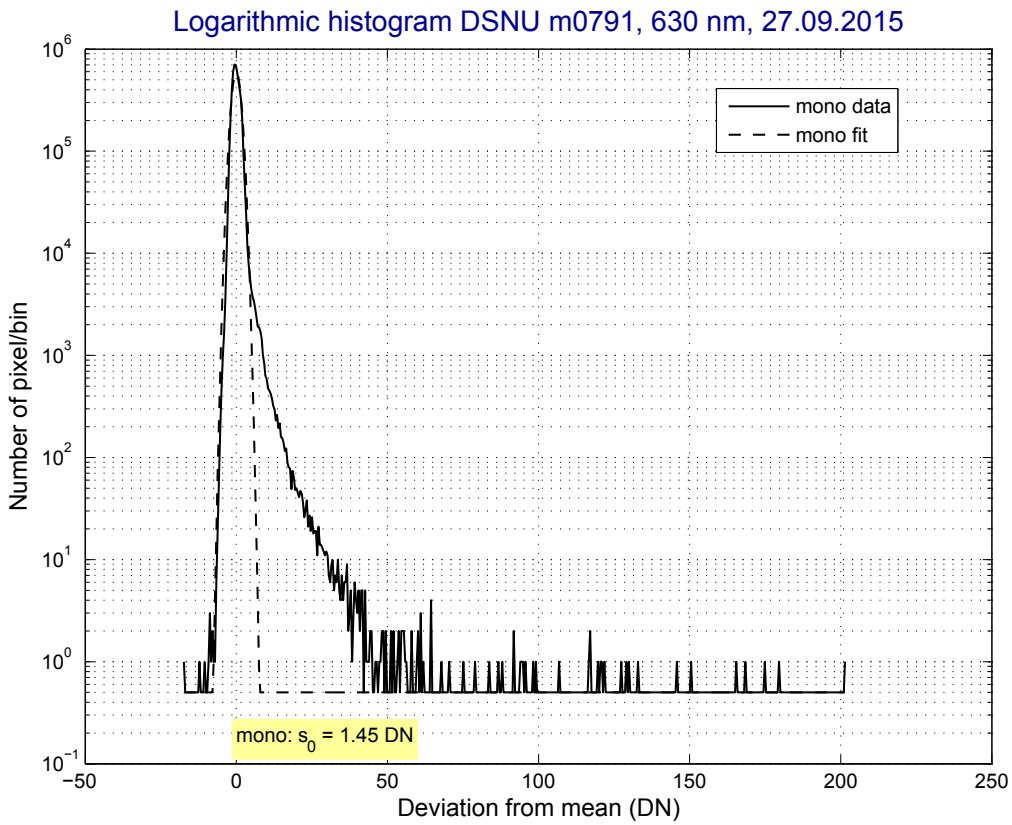
Signal-to-noise ratio in double-logarithmic presentation.

3.5 Nonuniformity: DSNU, PRNU, profiles, spectograms

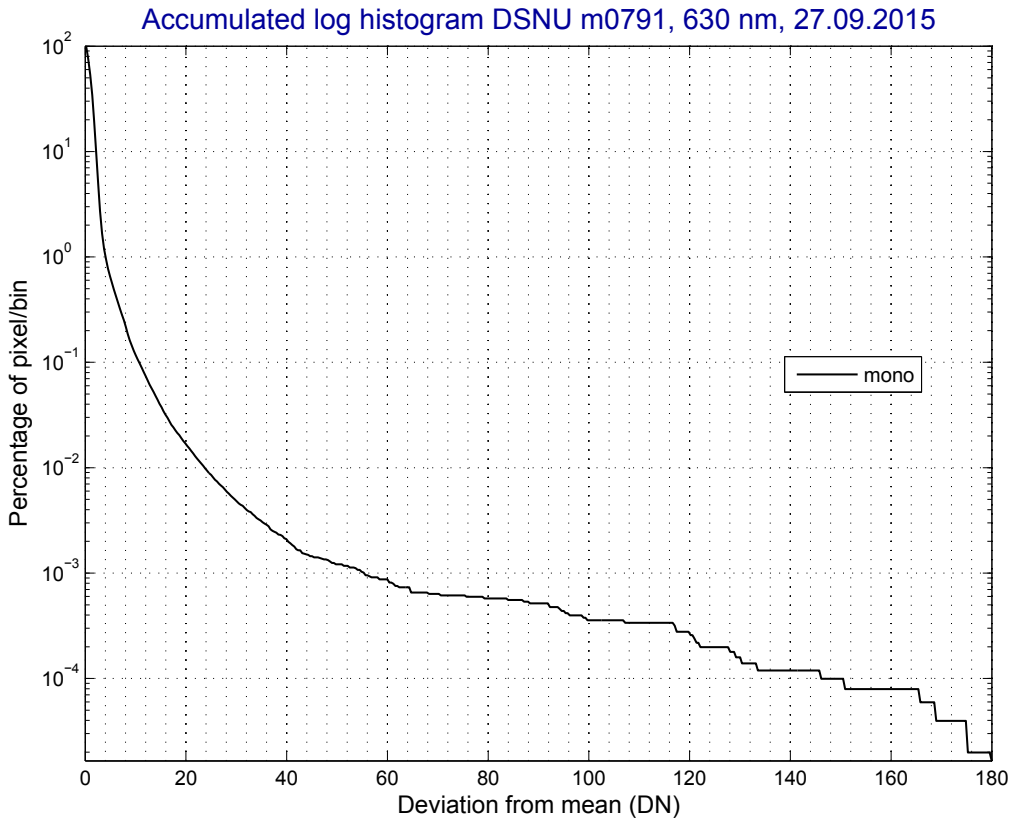
DSNU



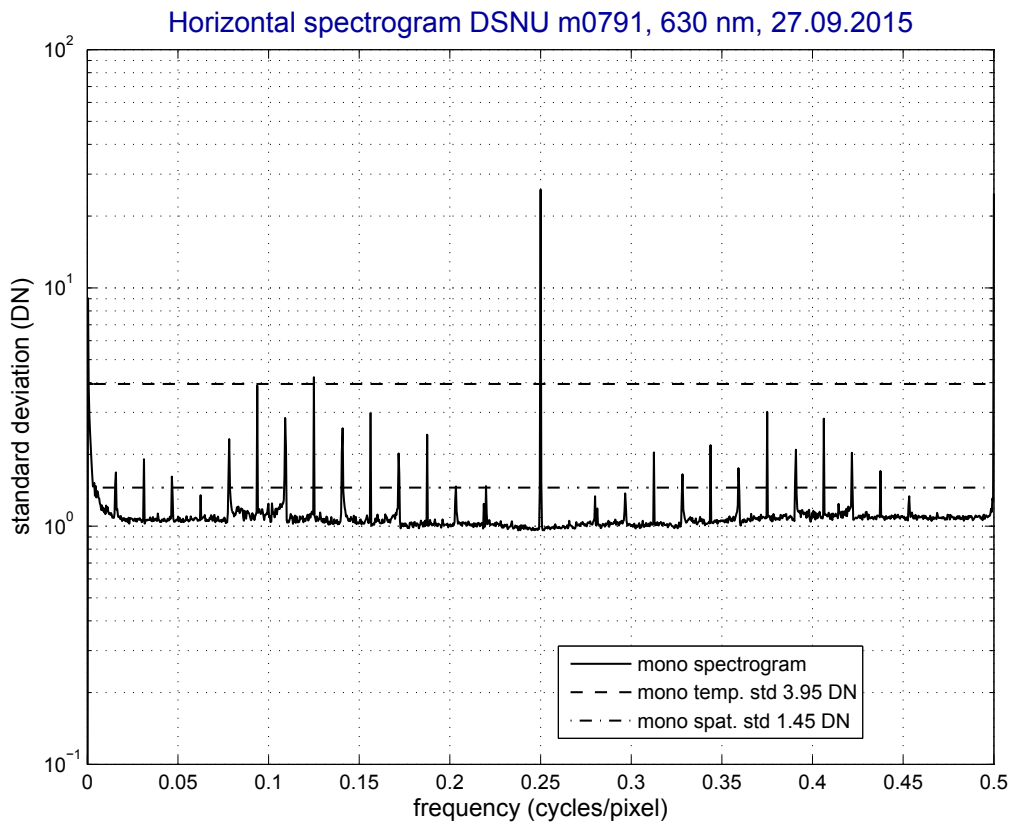
Contrast enhanced dark image, range 13.0 - 21.7 DN (not part of EMVA 1288 standard).



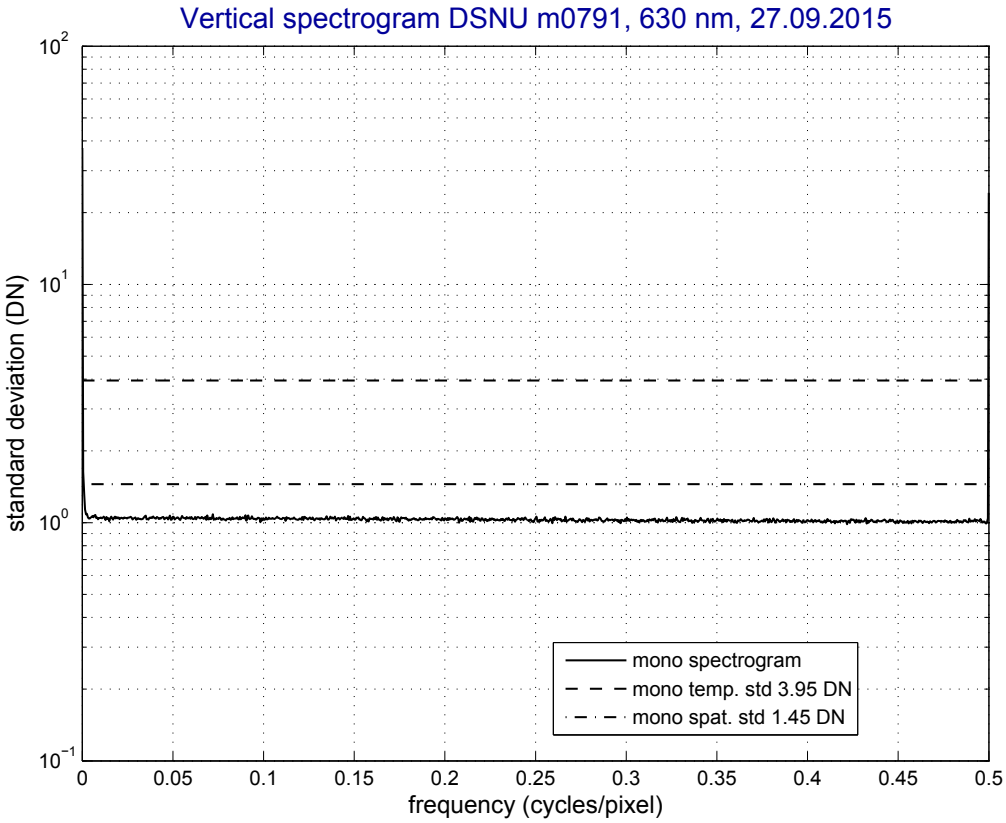
Logarithmic histogram of spatial deviation from mean in units DN.



Accumumulated logarithmic histogram of absolute spatial deviation from mean in units DN.

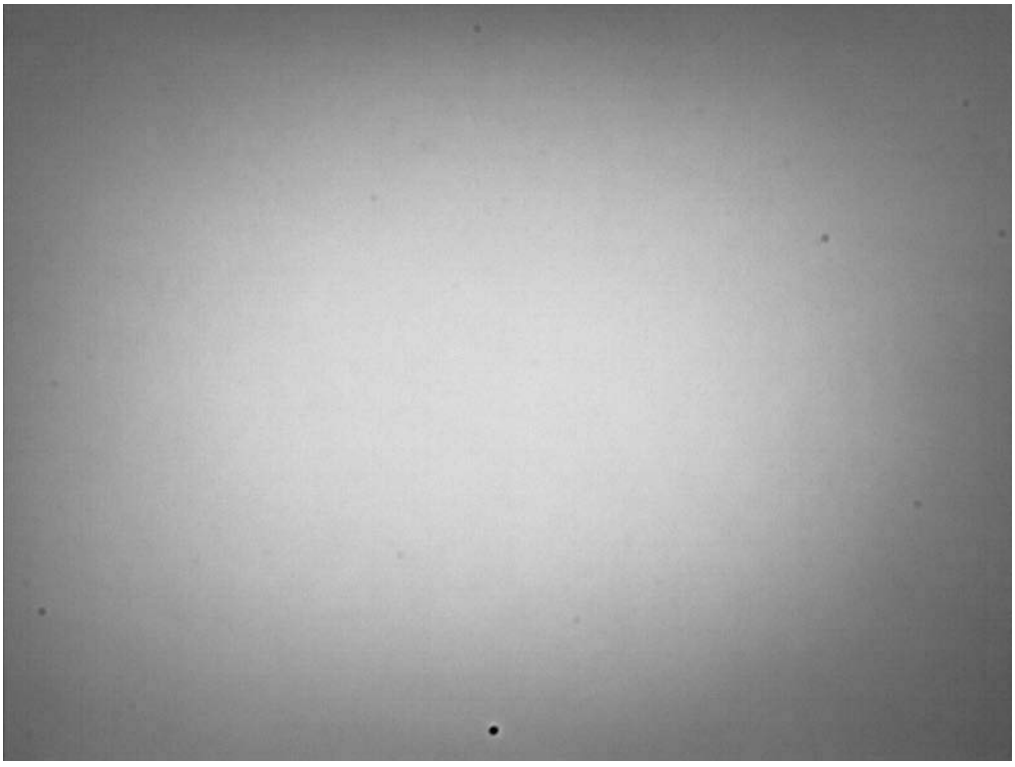


Horizontal spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

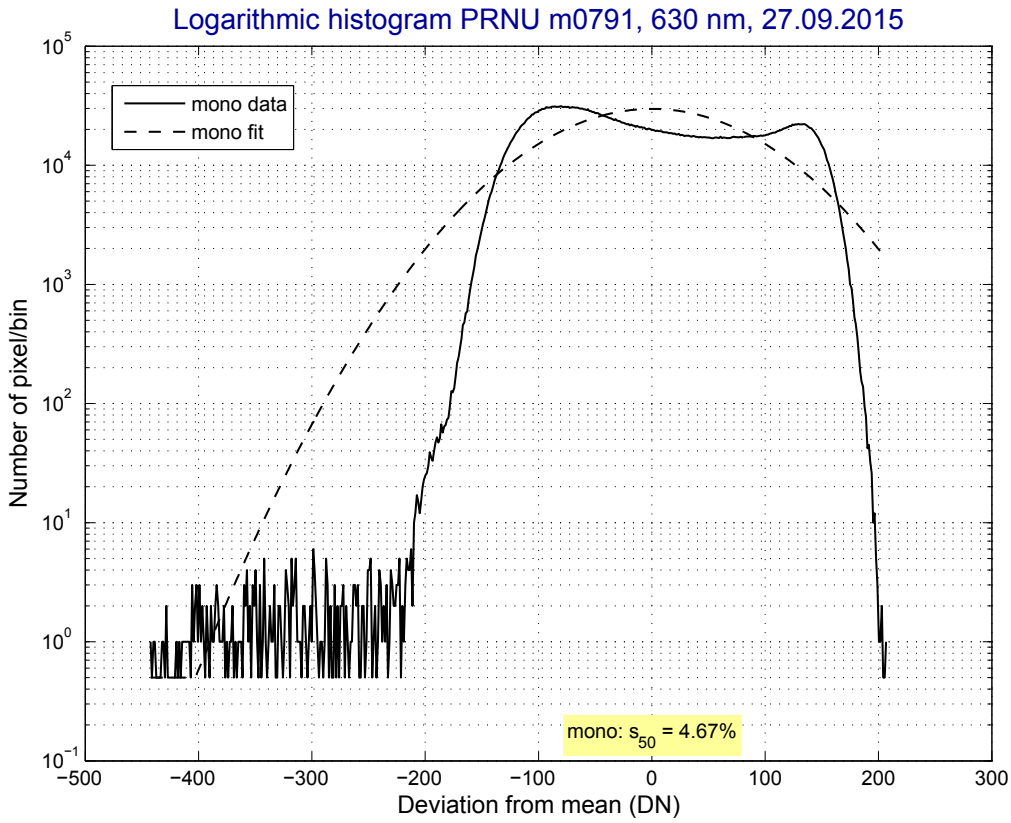


Vertical spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

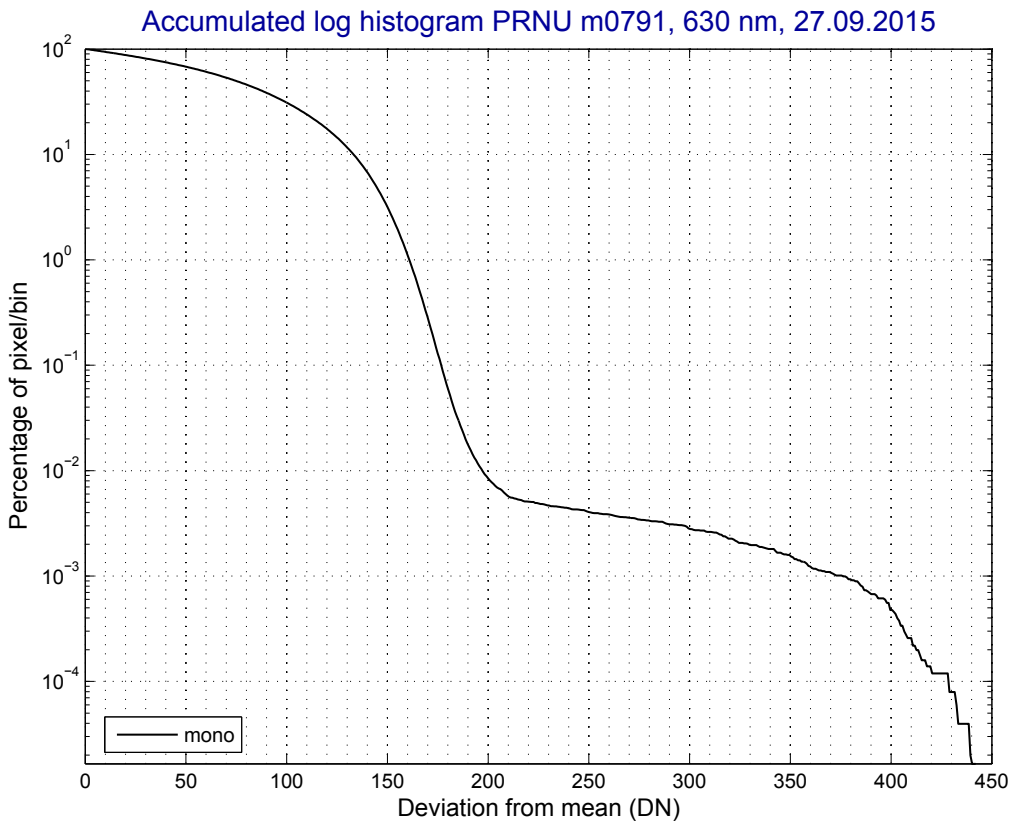
PRNU



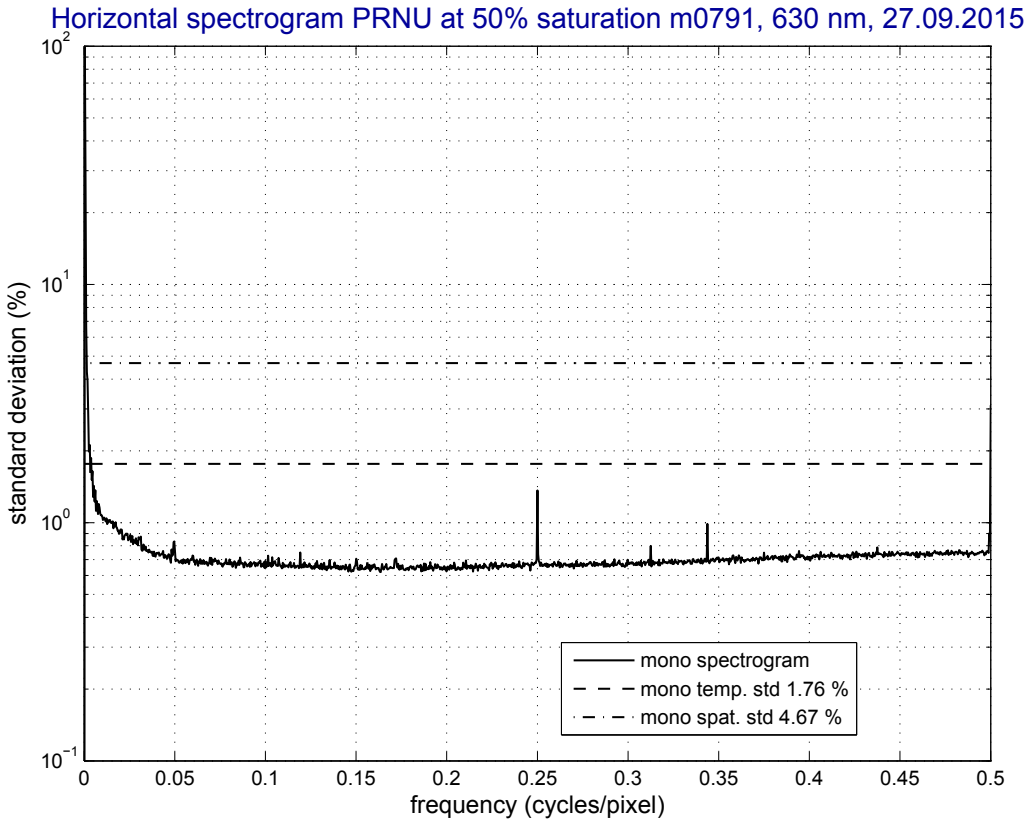
Contrast enhanced response image, range ±14.0% (not part of EMVA 1288 standard).



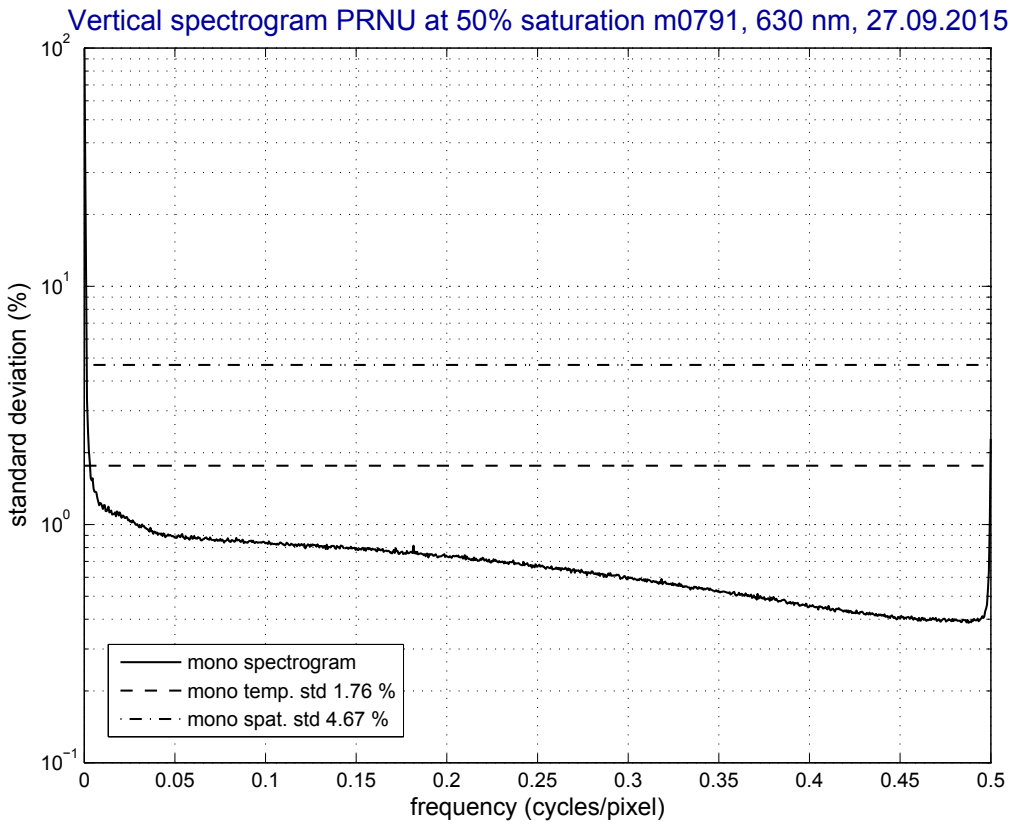
Logarithmic histogram of spatial deviation from mean in units %



Accumulated logarithmic histogram of absolute spatial deviation from mean in units %

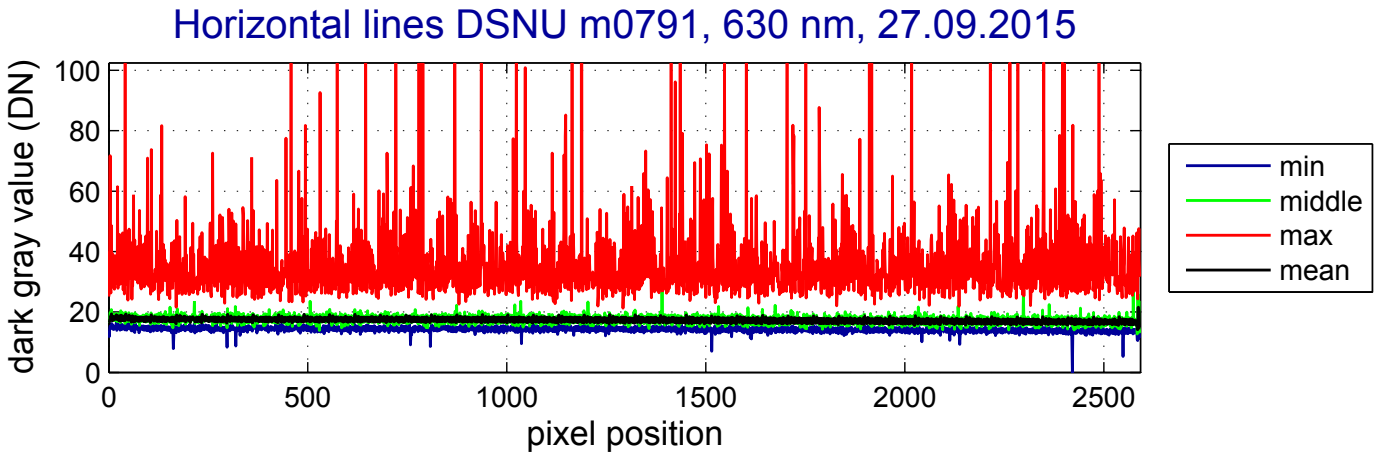


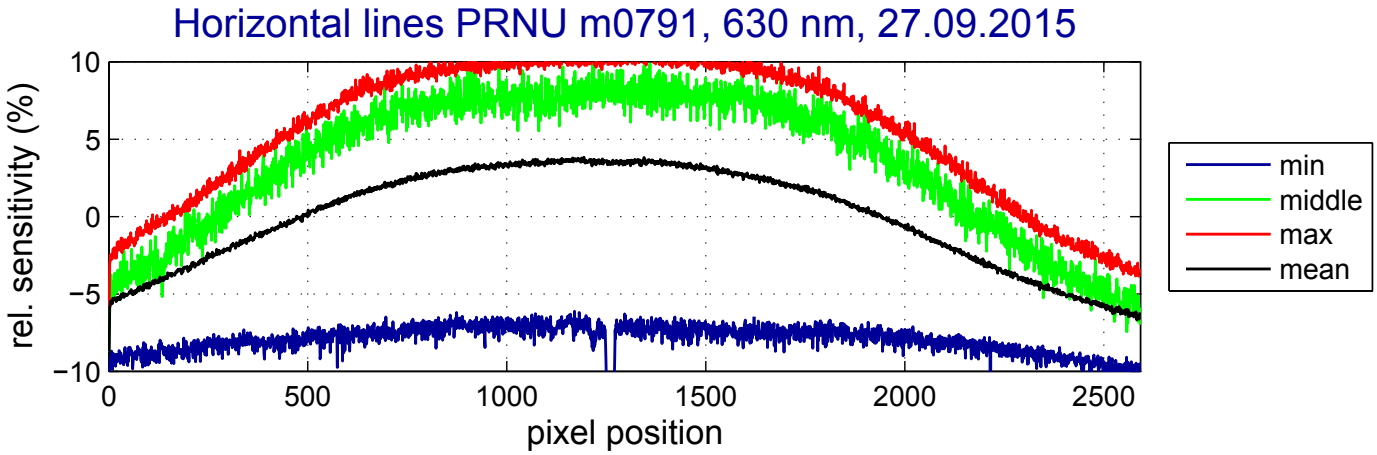
Horizontal spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.078%.



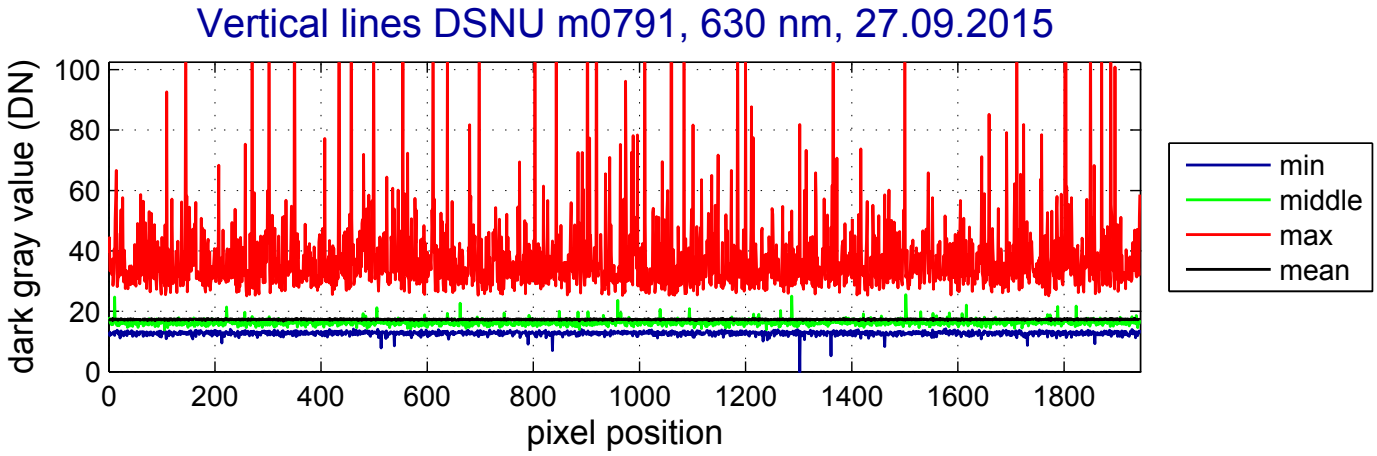
Vertical spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.078%.

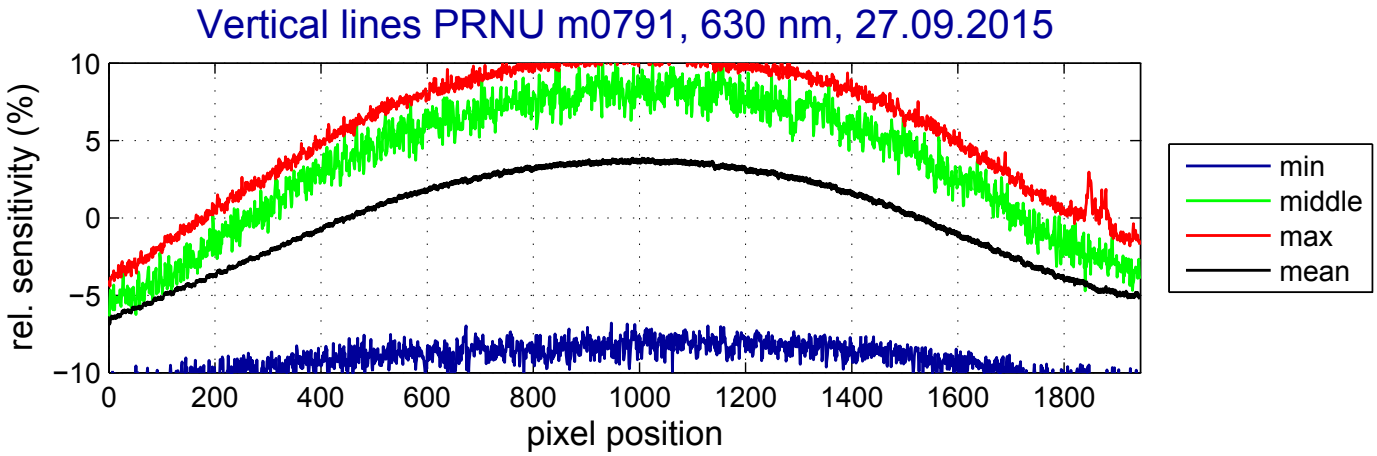
Horizontal and vertical profiles (preliminary, release 3.1)





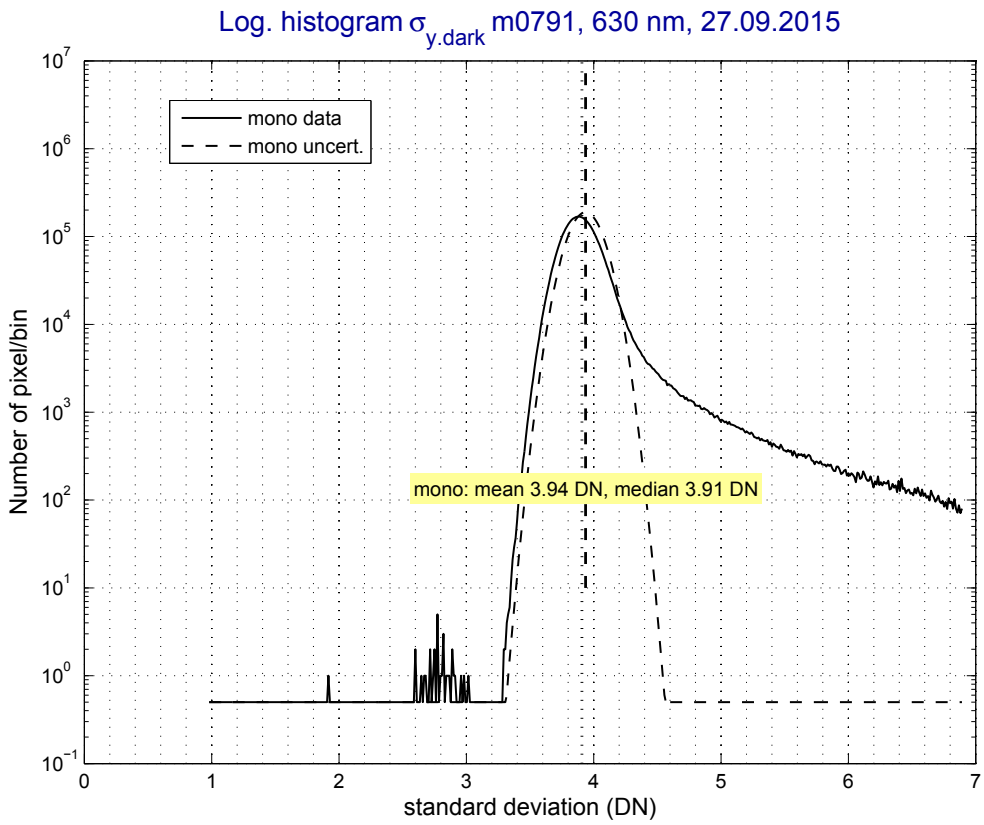
Horizontal profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.



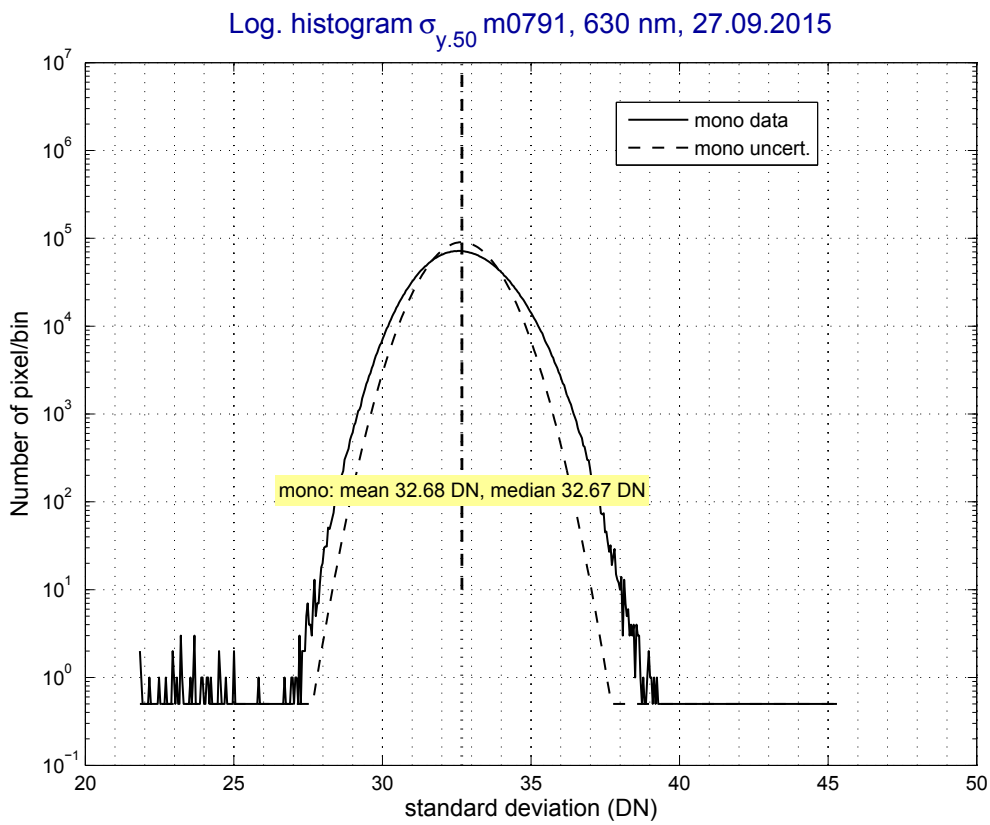


Vertical profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.

Spatial variation of temporal noise (extension to EMVA 1288)

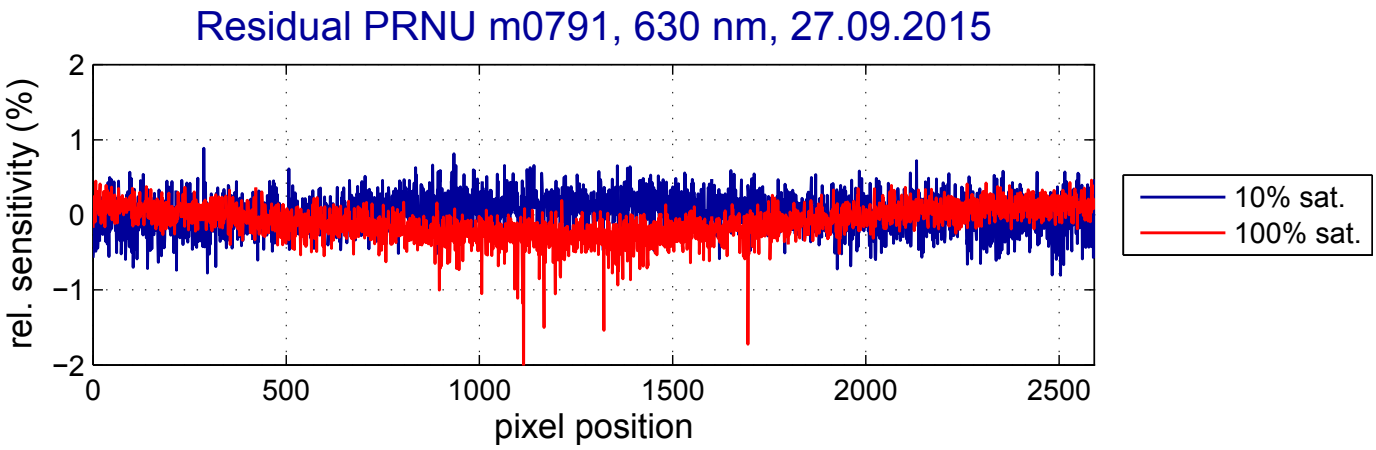


Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise in DN



Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise at 50% saturation in DN

Horizontal profiles residual PRNU (in extension to EMVA 1288)



Horizontal profiles of residual PRNU for middle line in % of mean after two-point calibration with dark image and 50% saturation image for a low and high saturation level.

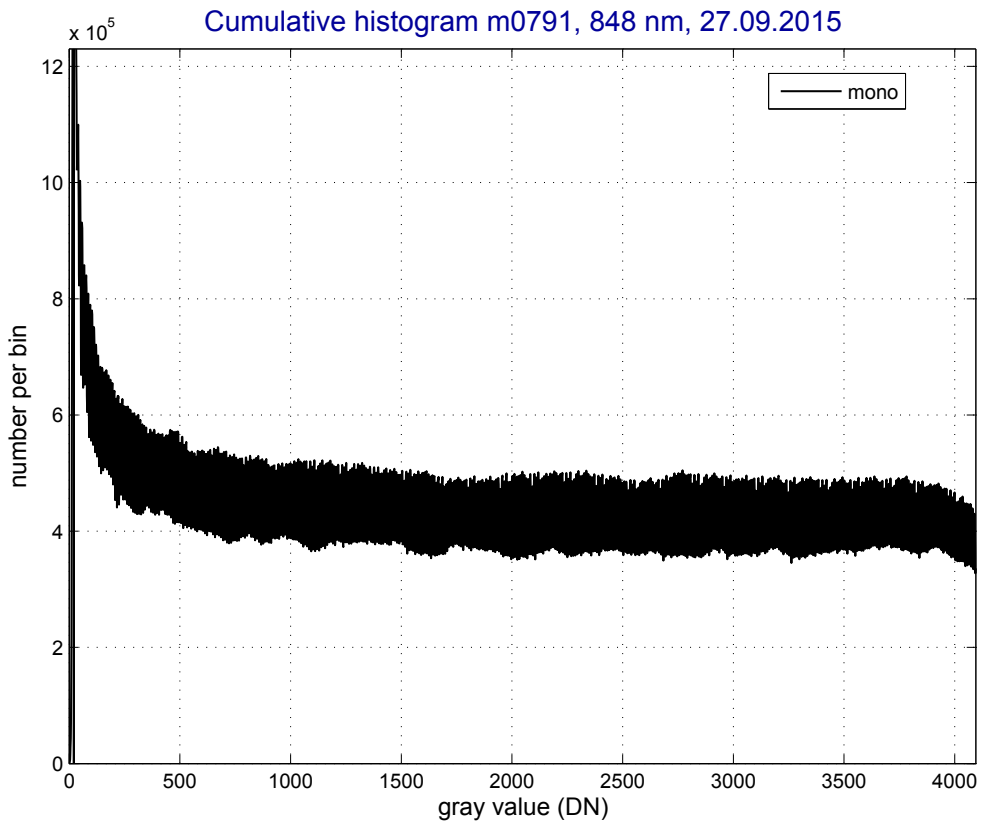
Table with residual inhomogeneities at different saturation levels after a two-point correction with dark image and 50% saturation image.

Saturation %	μ_y DN	σ_y DN	s_y DN	$\sigma_{\text{y.res}}$ DN	$s_{\text{y.corr}}$ DN	$s_{\text{y.corr}}$ %	$s_{\text{y.corr}}/s_y$ %
0	17.33	3.95	1.45	0.17	0.00	0.00	0.00
10	385.67	15.11	17.46	0.67	0.90	0.24	5.18
20	764.14	21.10	35.23	0.93	1.54	0.20	4.36
30	1126.58	25.61	51.94	1.13	1.55	0.14	2.99
40	1490.75	29.37	69.04	1.30	1.85	0.12	2.67
50	1855.69	32.73	85.96	1.45	0.05	0.00	0.06
60	2224.11	35.74	102.61	1.58	2.58	0.12	2.51
70	2590.78	38.44	119.16	1.70	3.16	0.12	2.65
80	2974.35	41.01	136.61	1.81	3.78	0.13	2.77
90	3339.53	43.20	152.79	1.91	4.90	0.15	3.21
100	3704.46	44.99	168.02	1.99	6.83	0.18	4.07

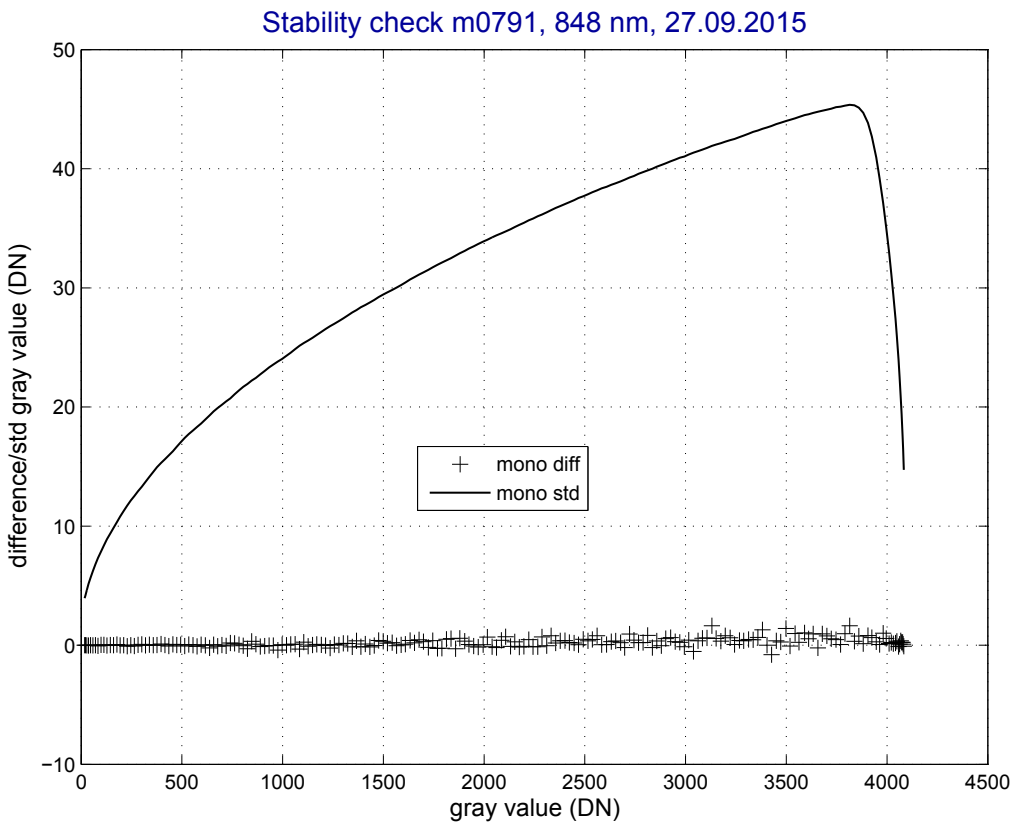
Detailed Data Operating Point 4, 848 nm

Contents

4.1 Checks for Correctness of Measurements and EMVA 1288 Model



Gray value histogram accumulated over all illumination steps (plot in extension of EMVA1288 standard).



Stability check: temporal standard deviation (line) and difference of mean of two images (crosses) for all illumination steps (plot in extension of EMVA1288 standard).

Covariance coefficients of neighboring pixels averaged over the whole image sensor. Values unequal zero except for coefficient without shift, which is one, indicate some kind of preprocessing. This makes the central assumption of the linear EMVA 1288 model invalid. The gain K will then be lower and the quantum efficiency η higher than the true values.

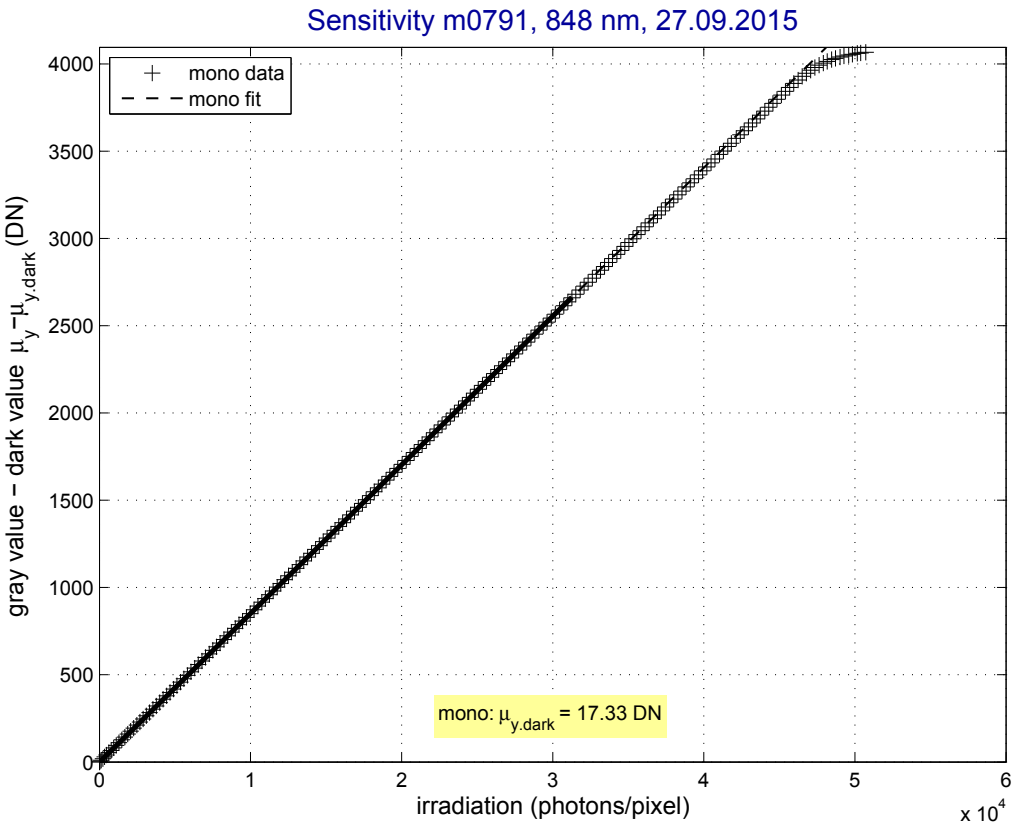
List of covariance coefficients in 9×9 neighborhood, dark image (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.002	0.024	0.000	0.035	0.000	0.030	0.000	0.034
0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.000
0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.004
0.001	0.000	0.001	0.001	0.002	0.001	0.001	0.001	0.001
0.001	0.002	0.001	0.002	0.000	0.001	0.000	0.002	0.003
0.001	0.000	0.000	0.001	0.001	0.002	0.001	0.000	0.000
0.003	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.002
0.001	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.001
0.003	0.001	0.002	0.000	0.001	0.001	0.000	0.000	0.003

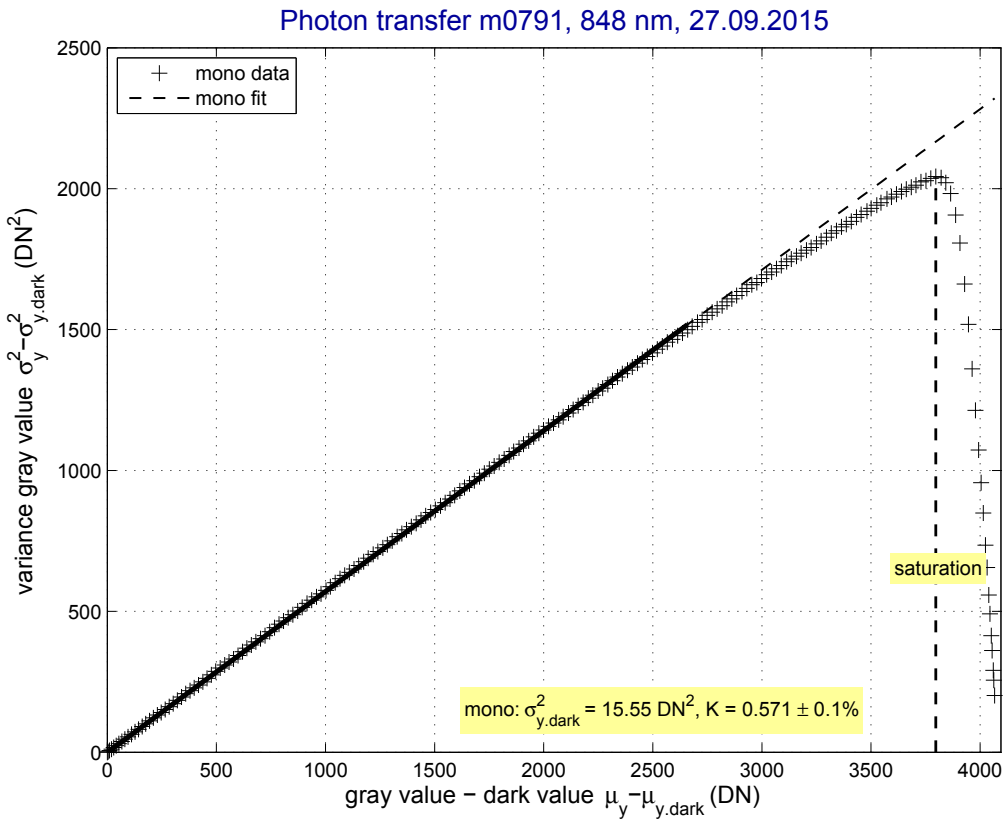
List of covariance coefficients in 9×9 neighborhood, 70% saturation (standard deviation of coefficients for uncorrelated pixel: 0.0004):

1.000	0.006	0.034	0.000	0.005	0.000	0.001	0.001	0.002
0.003	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000
0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000
0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
0.001	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.001
0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001
0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000

4.2 Sensitivity and Noise

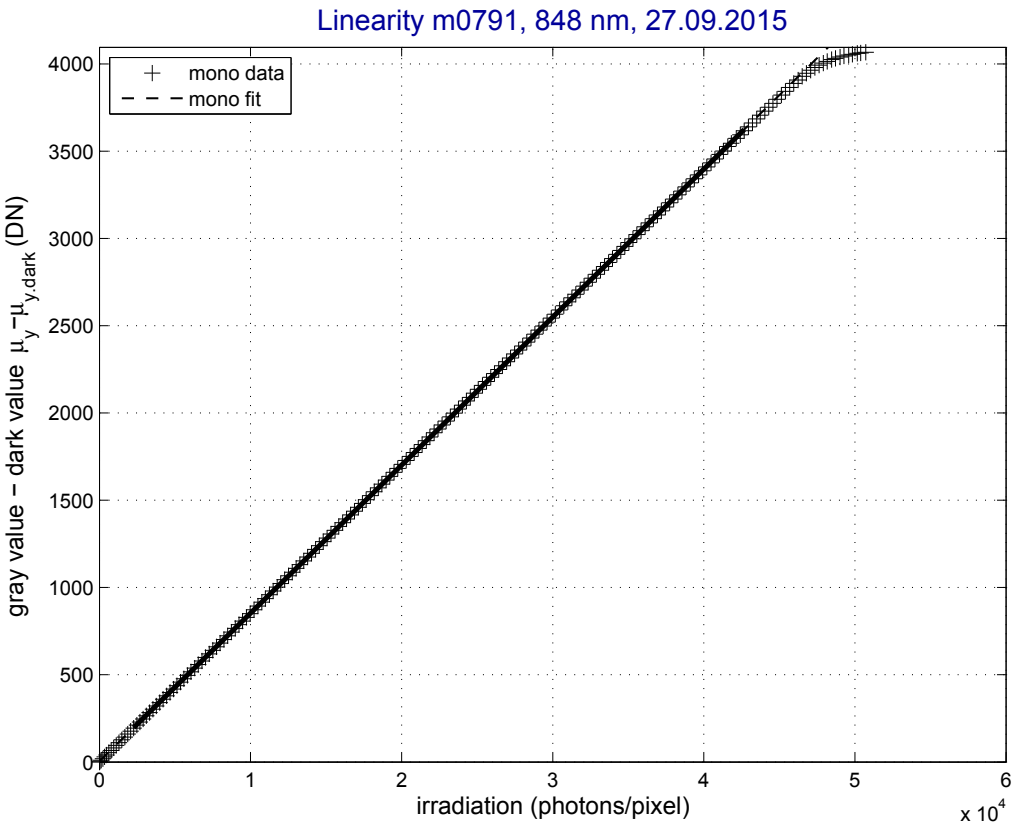


Characteristics camera curve (sensitivity plot) with 201 illumination steps.

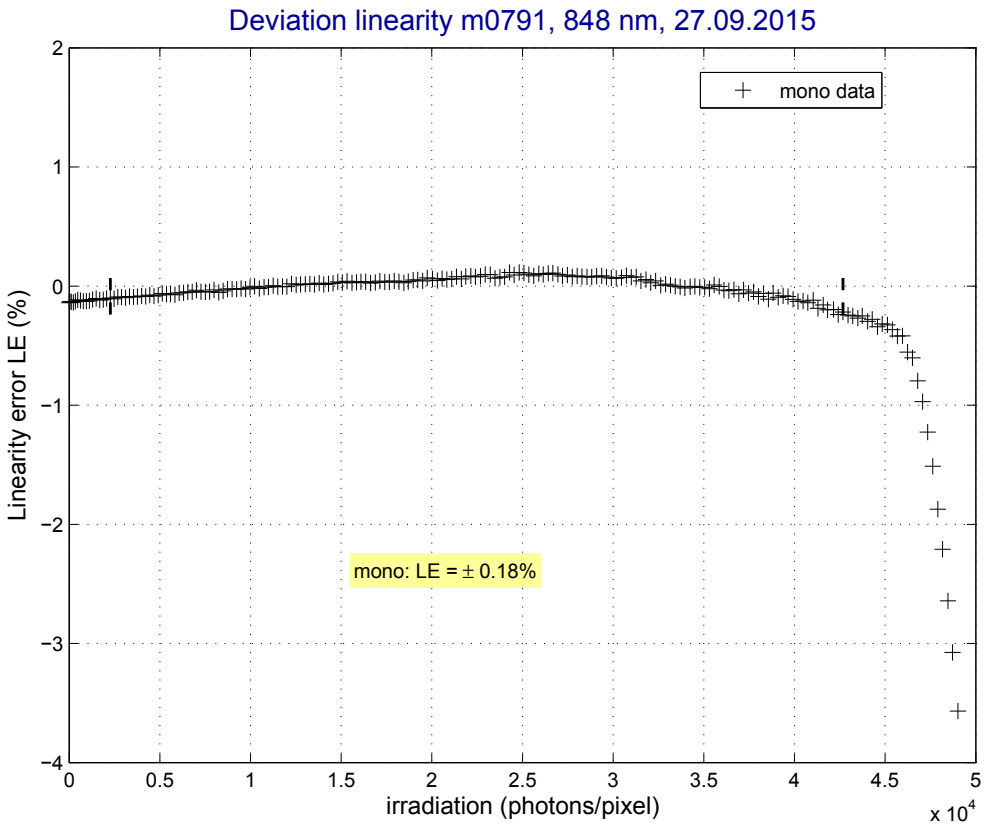


Photon transfer curve with 201 illumination steps.

4.3 Linearity

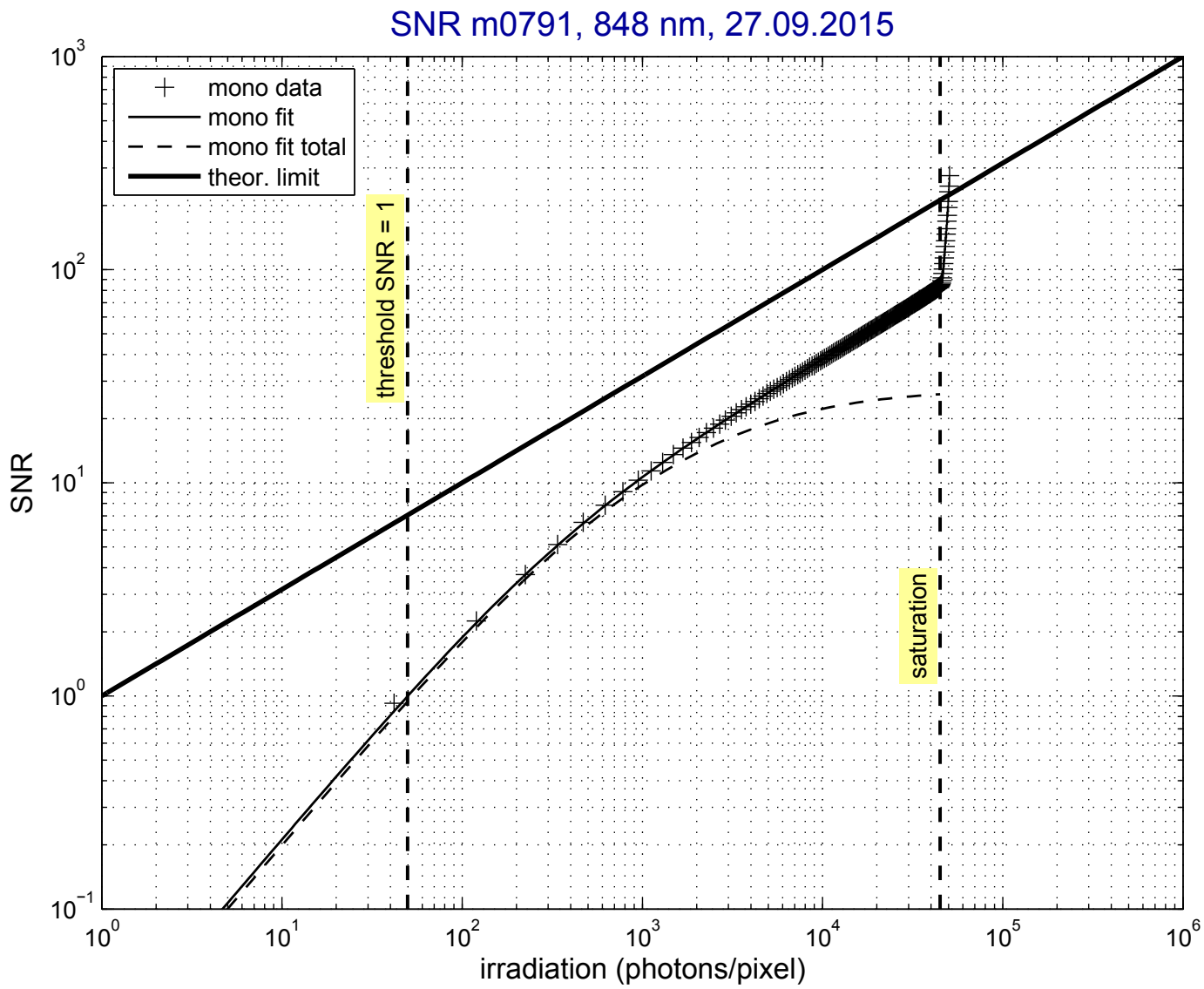


Linearity curve.



Deviation from linearity.

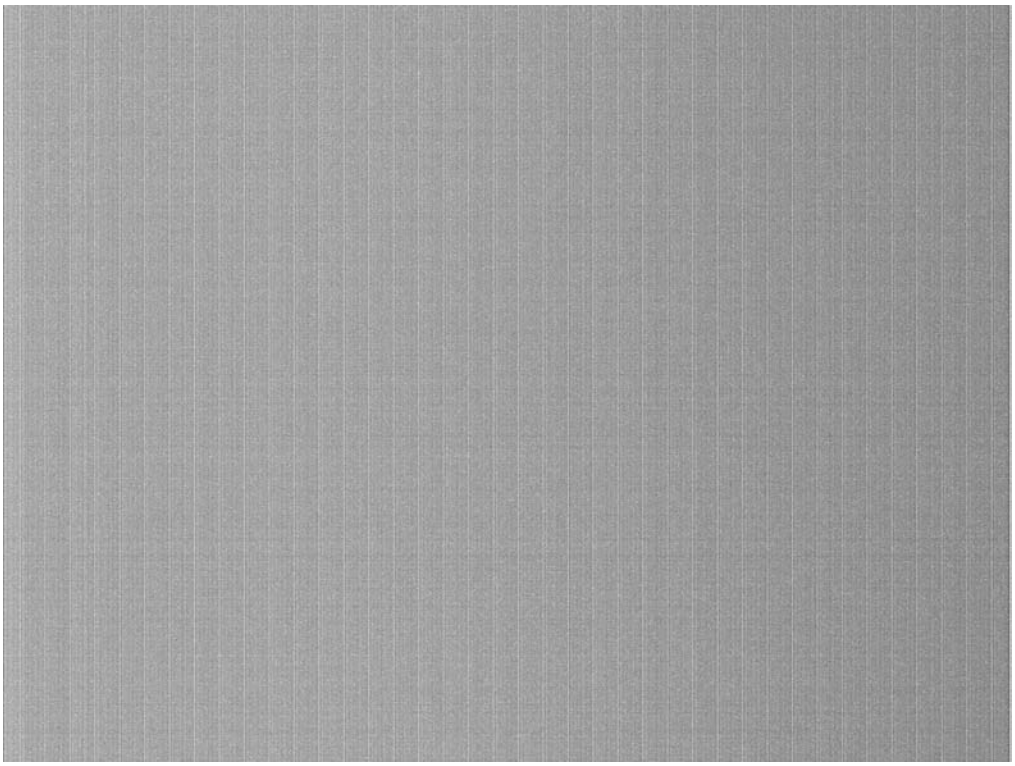
4.4 Signal-to-Noise Ratio (SNR)



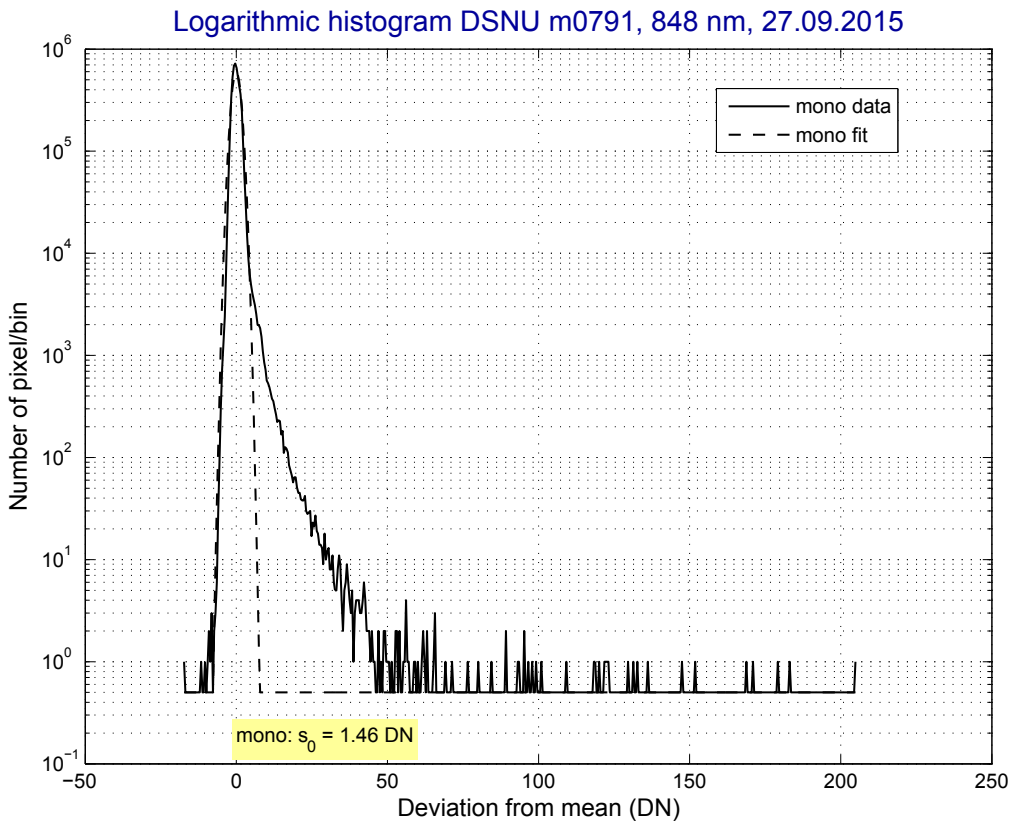
Signal-to-noise ratio in double-logarithmic presentation.

4.5 Nonuniformity: DSNU, PRNU, profiles, spectograms

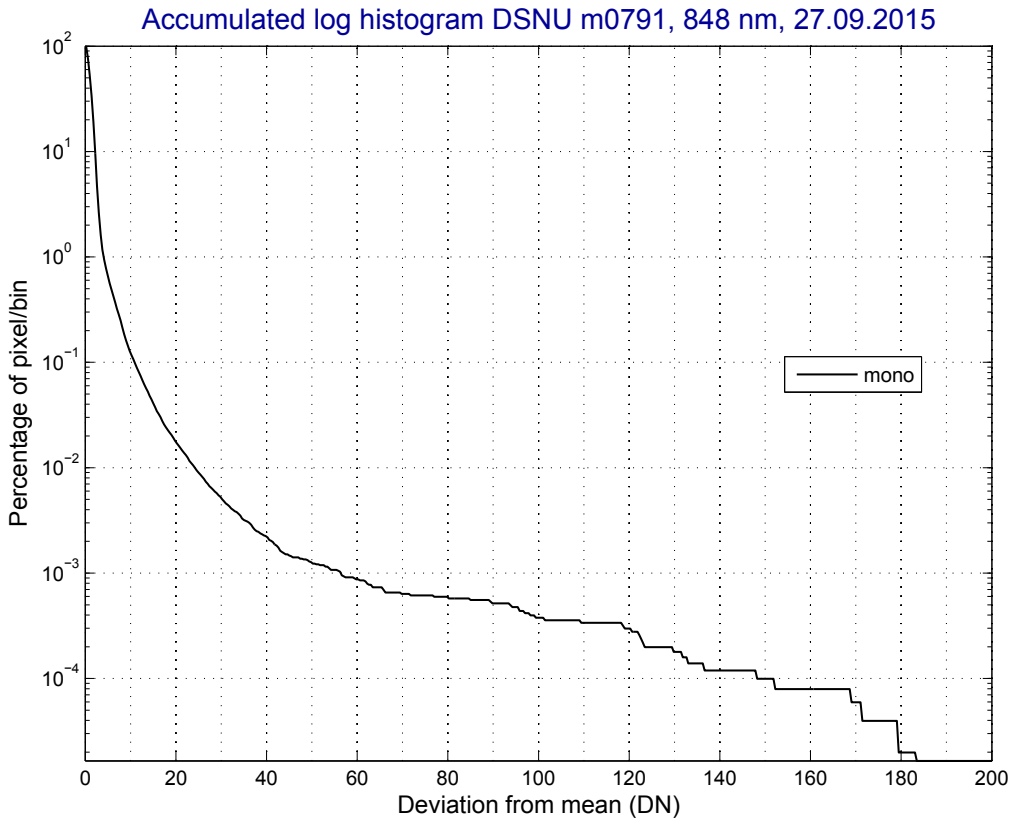
DSNU



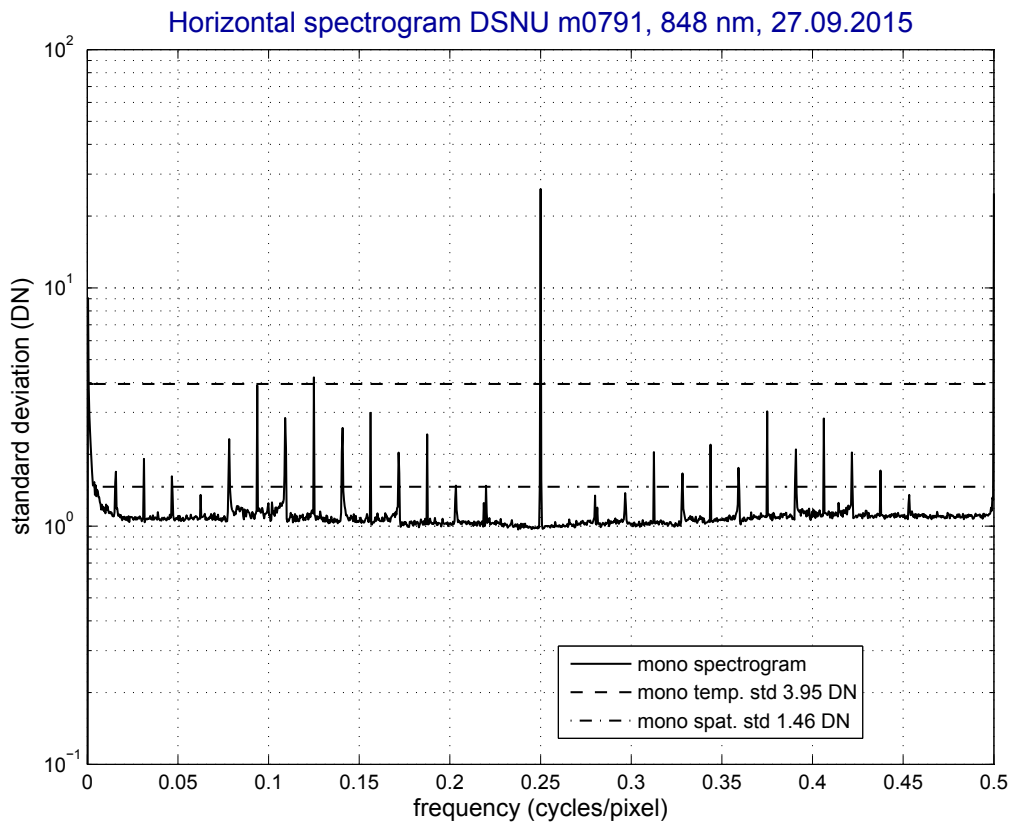
Contrast enhanced dark image, range 12.9 - 21.7 DN (not part of EMVA 1288 standard).



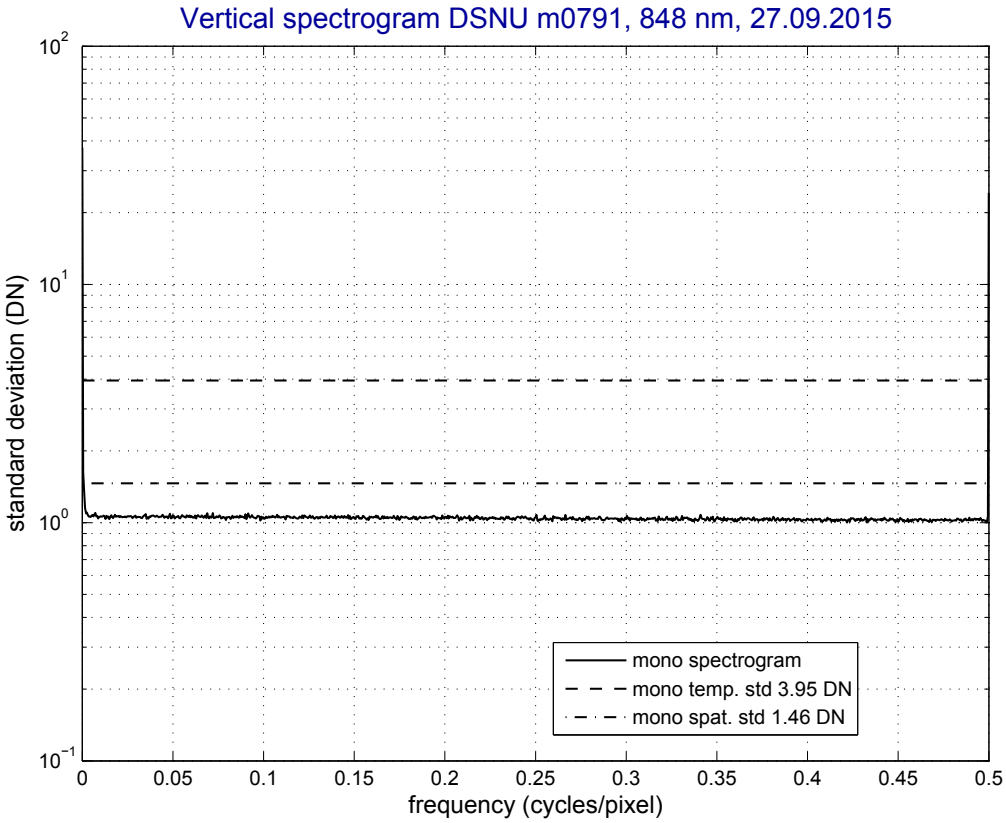
Logarithmic histogram of spatial deviation from mean in units DN.



Accumumulated logarithmic histogram of absolute spatial deviation from mean in units DN.



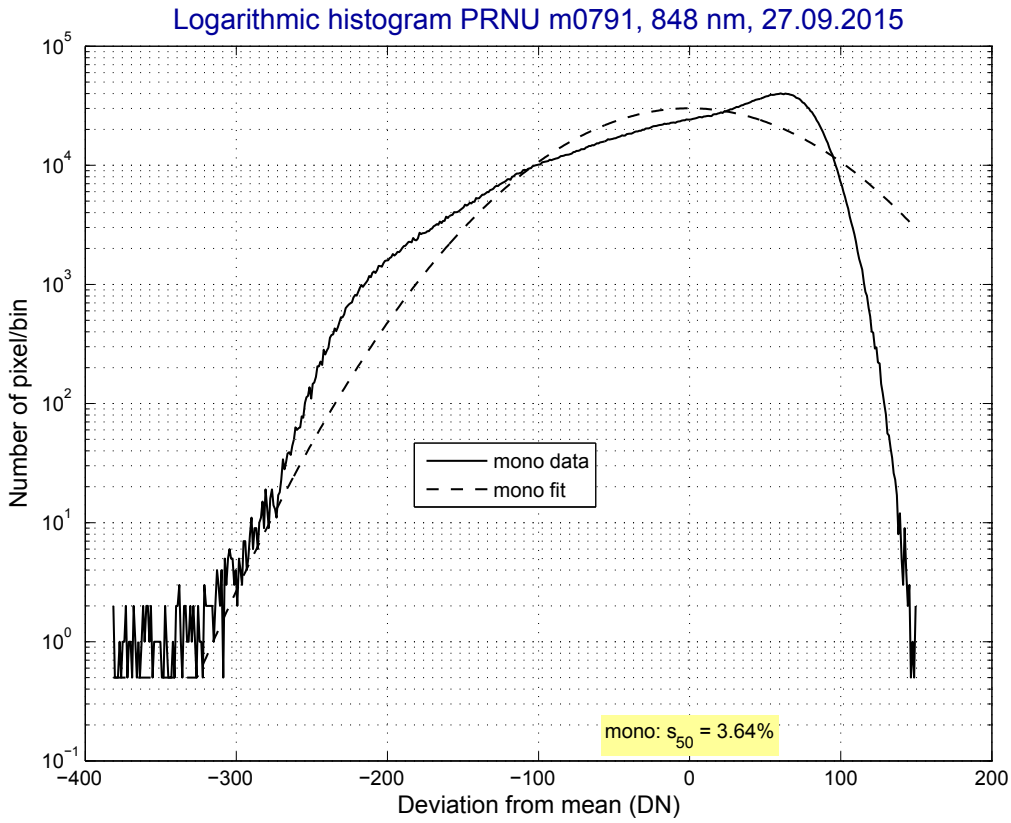
Horizontal spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.



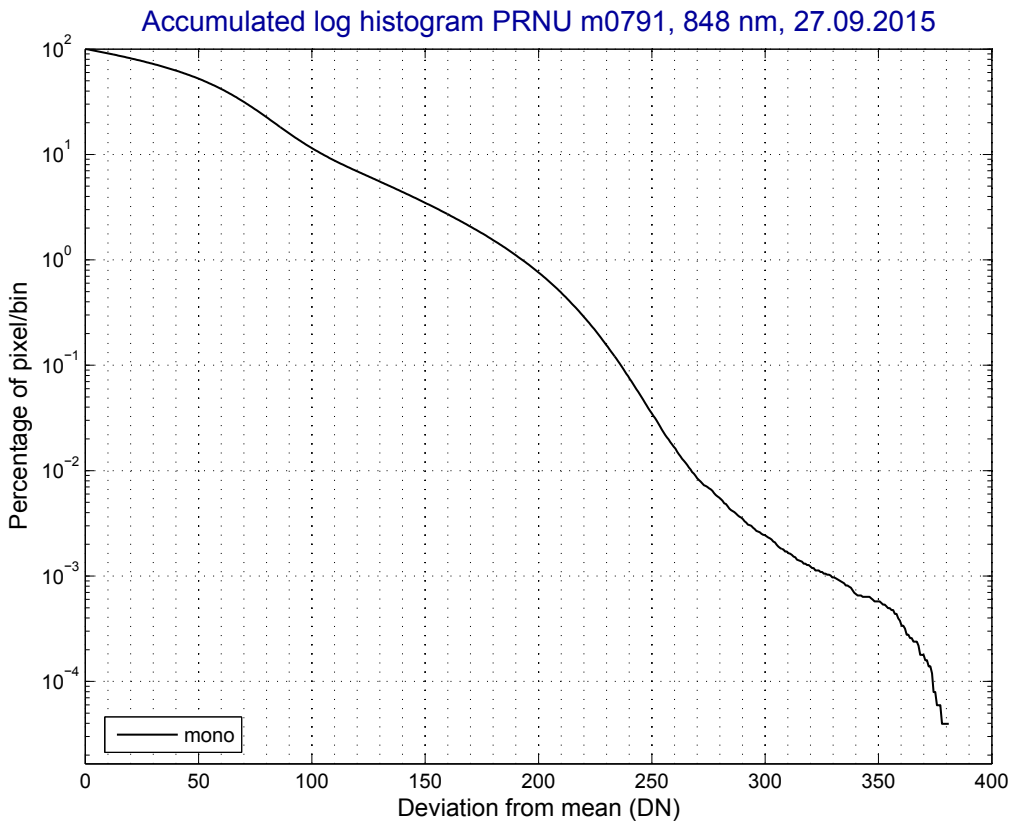
Vertical spectrogram of dark image averaged over 512 images, standard deviation of residual temporal noise is 0.17 DN.

PRNU

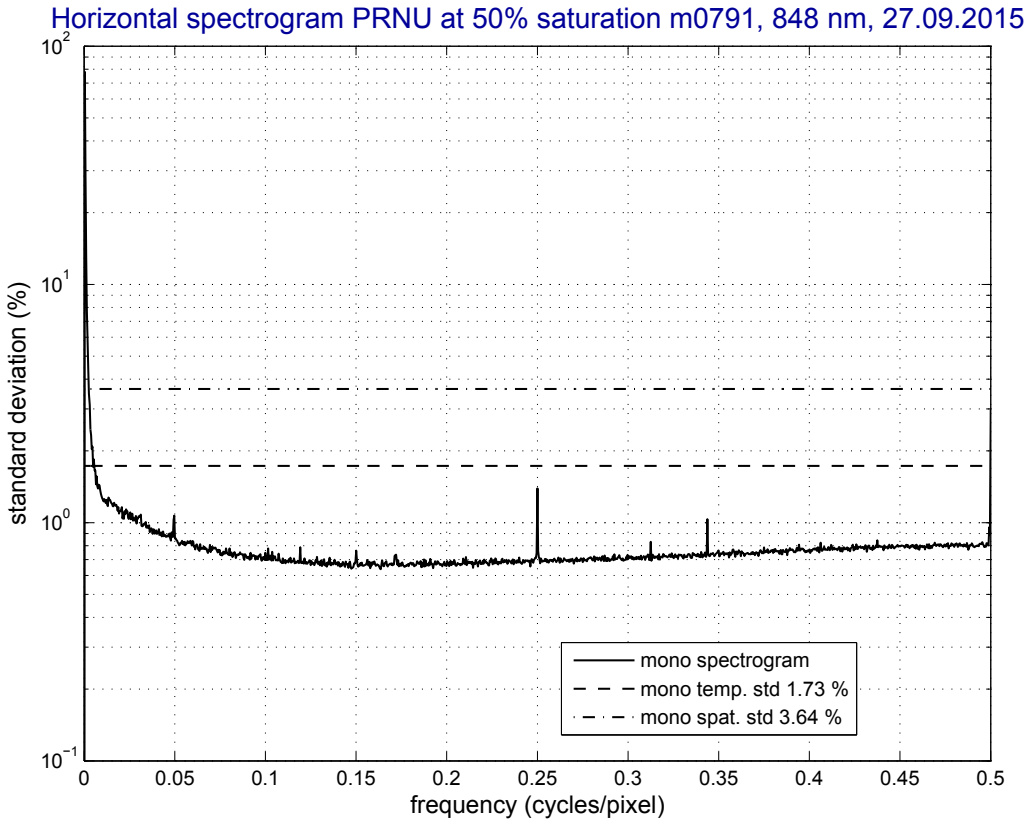
Contrast enhanced response image, range ±10.9% (not part of EMVA 1288 standard).



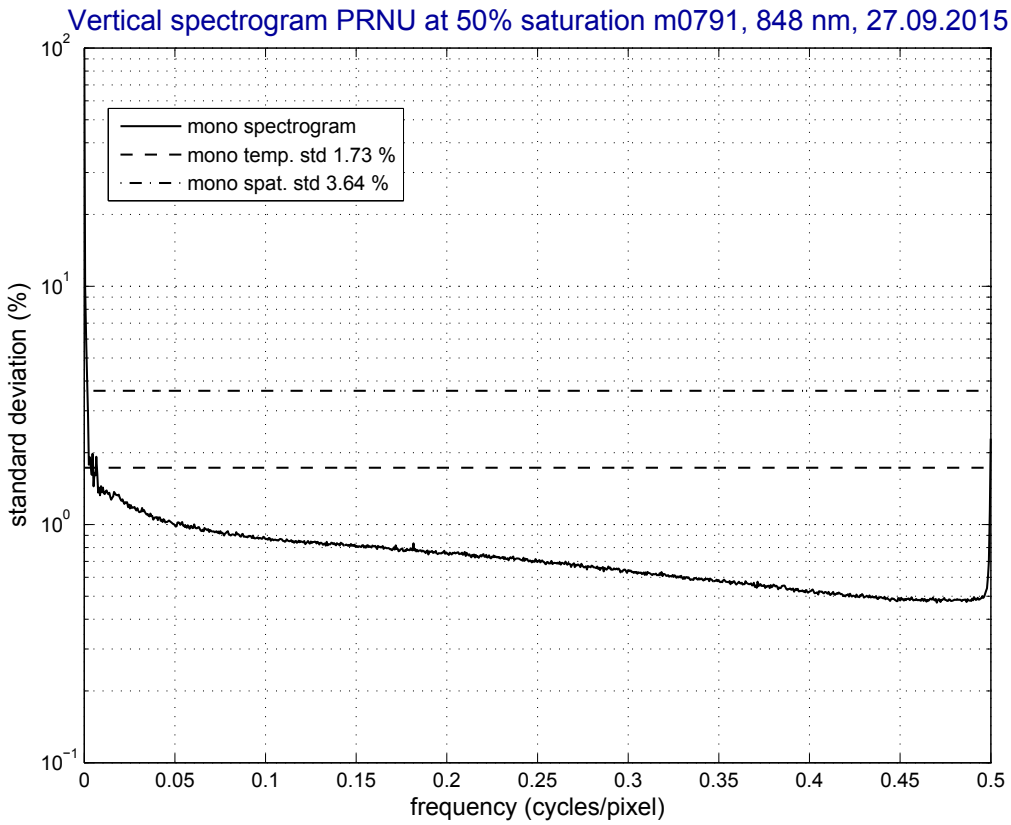
Logarithmic histogram of spatial deviation from mean in units %



Accumulated logarithmic histogram of absolute spatial deviation from mean in units %

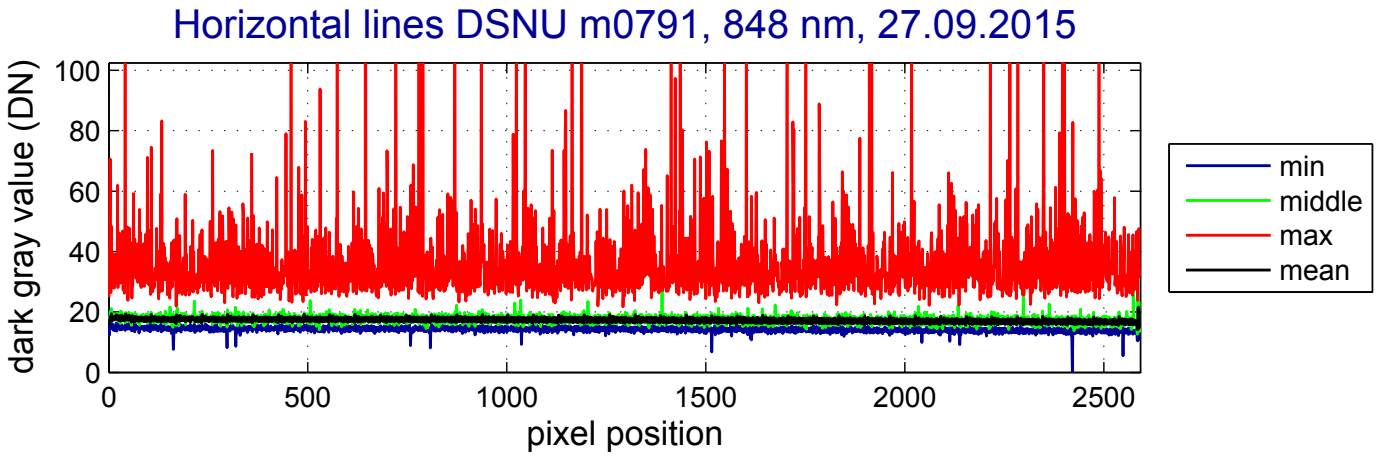


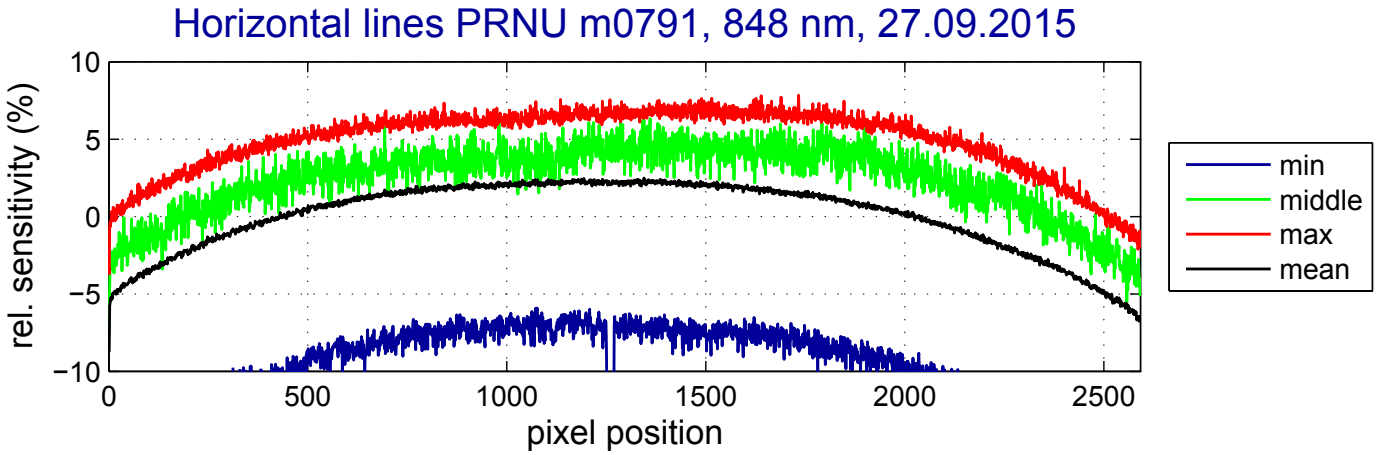
Horizontal spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.076%.



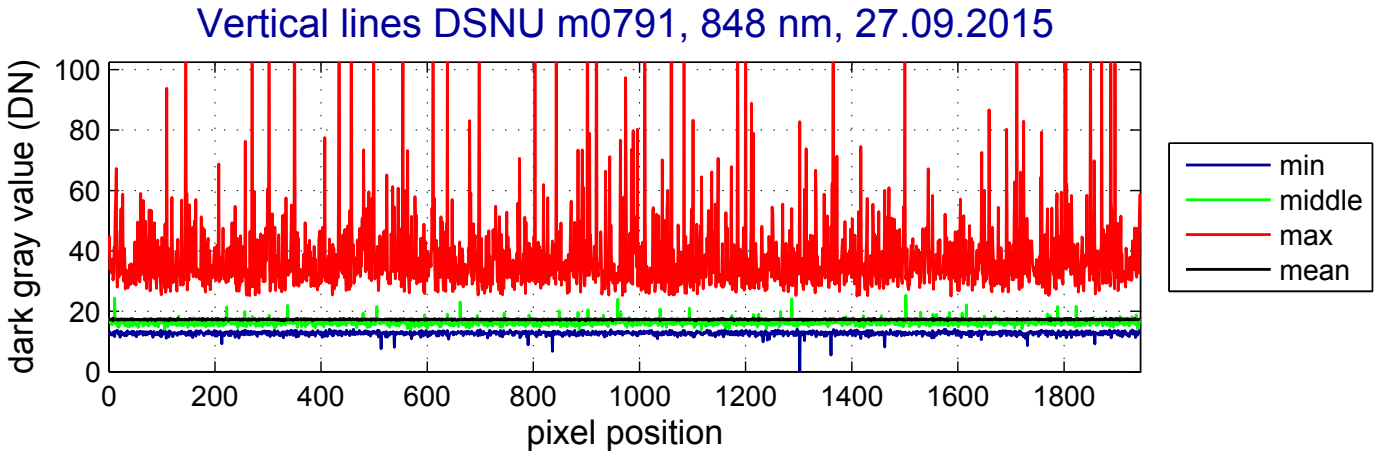
Vertical spectrogram of response image averaged over 512 images, standard deviation of residual temporal noise is 0.076%.

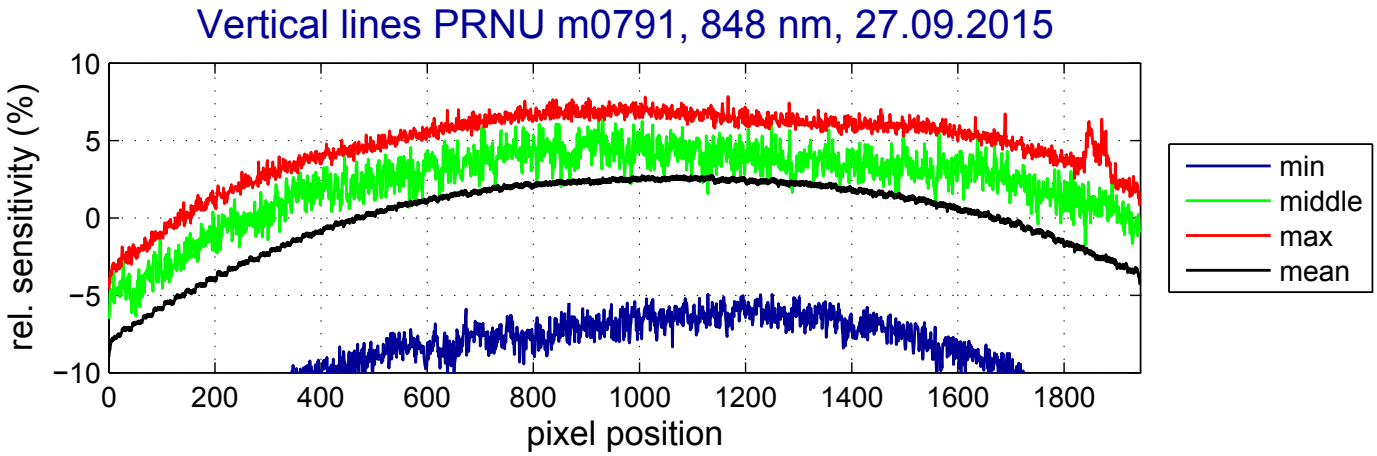
Horizontal and vertical profiles (preliminary, release 3.1)





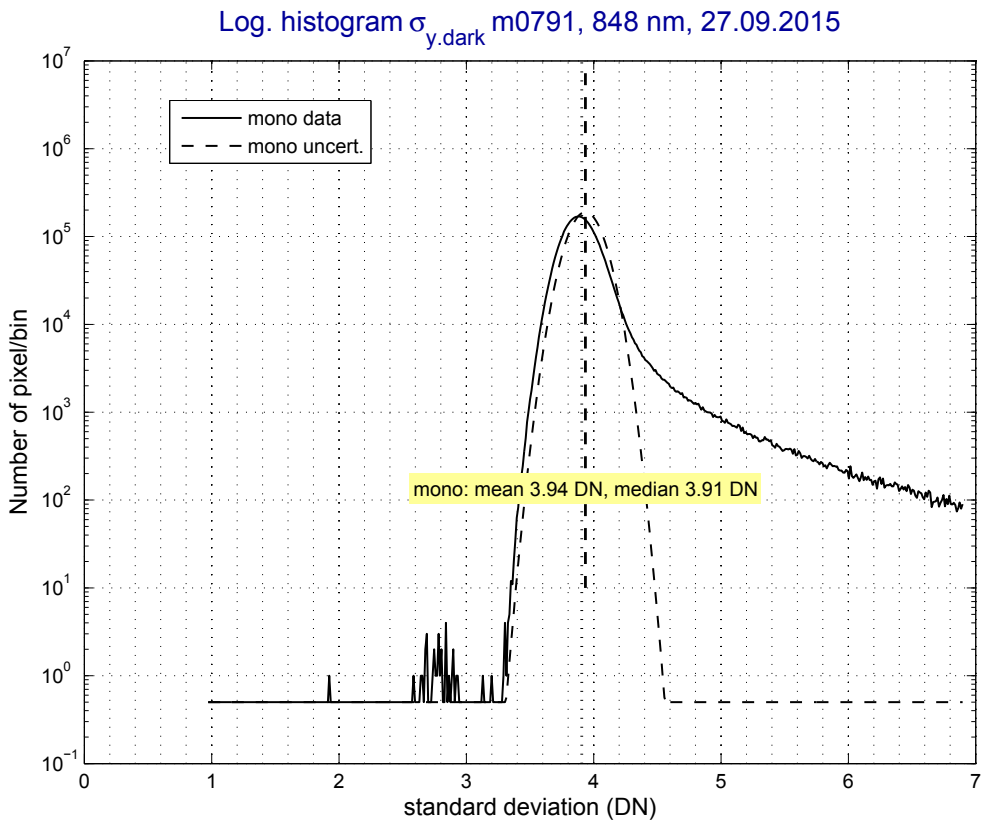
Horizontal profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.



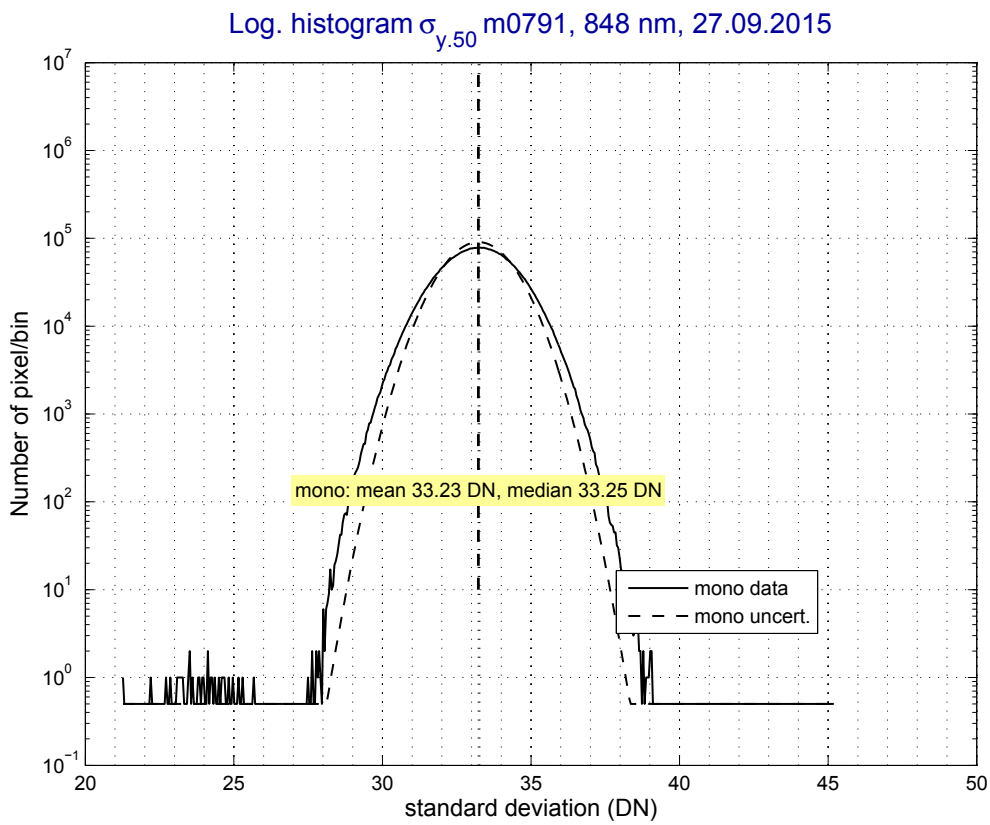


Vertical profiles of dark image in units DN (2.5% of full range shown) and of response image in % deviation from mean.

Spatial variation of temporal noise (extension to EMVA 1288)

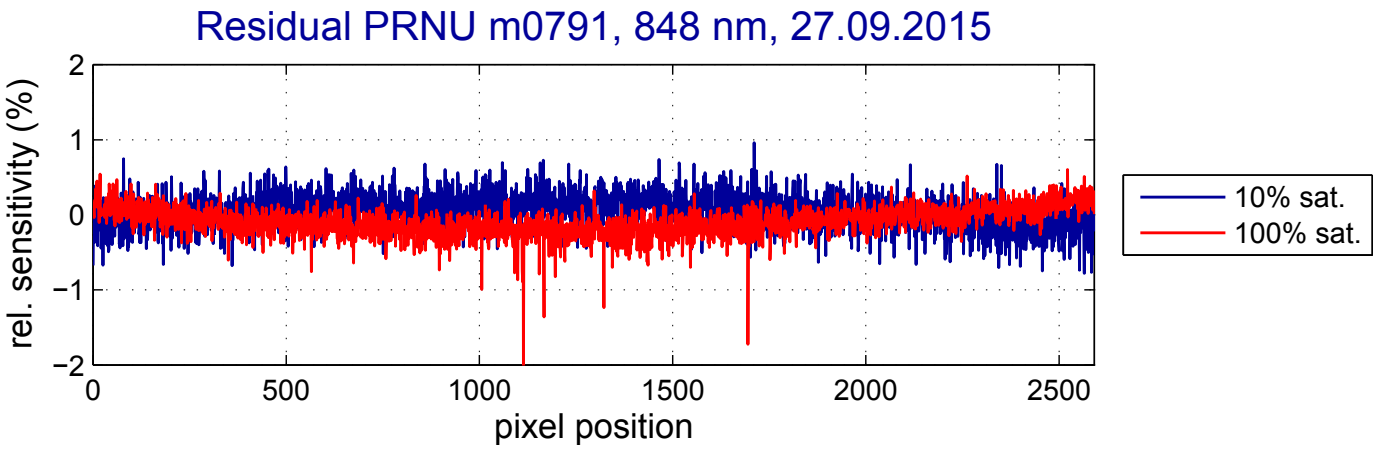


Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise in DN



Logarithmic histogram of spatial distribution of standard deviation of temporal dark noise at 50% saturation in DN

Horizontal profiles residual PRNU (in extension to EMVA 1288)



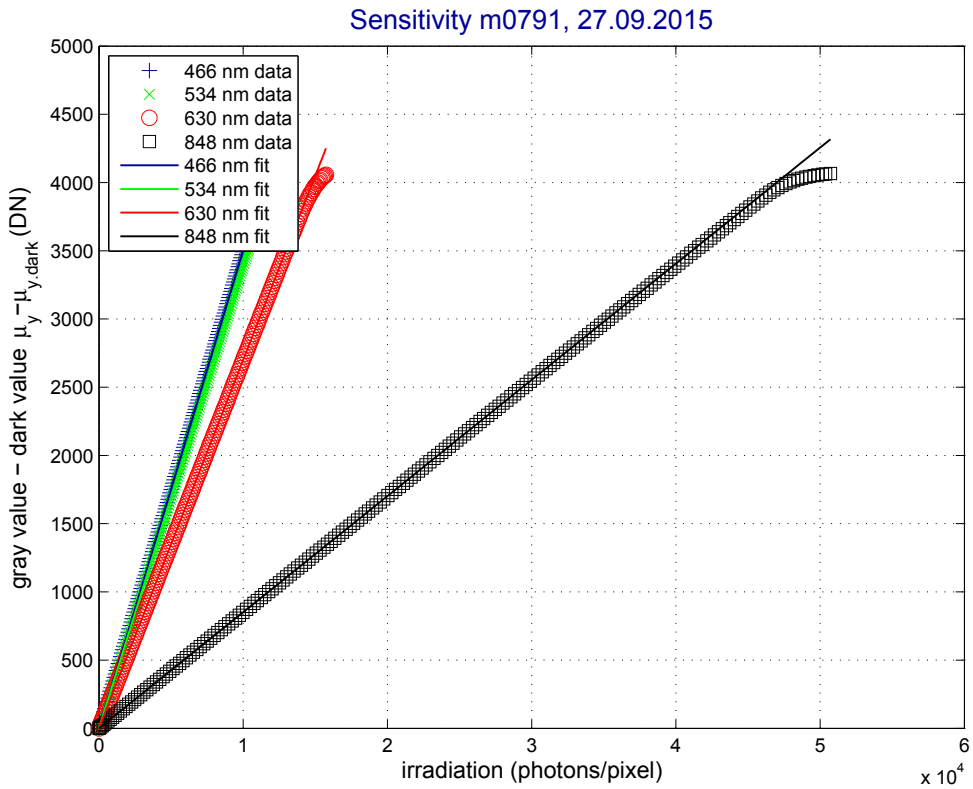
Horizontal profiles of residual PRNU for middle line in % of mean after two-point calibration with dark image and 50% saturation image for a low and high saturation level.

Table with residual inhomogeneities at different saturation levels after a two-point correction with dark image and 50% saturation image.

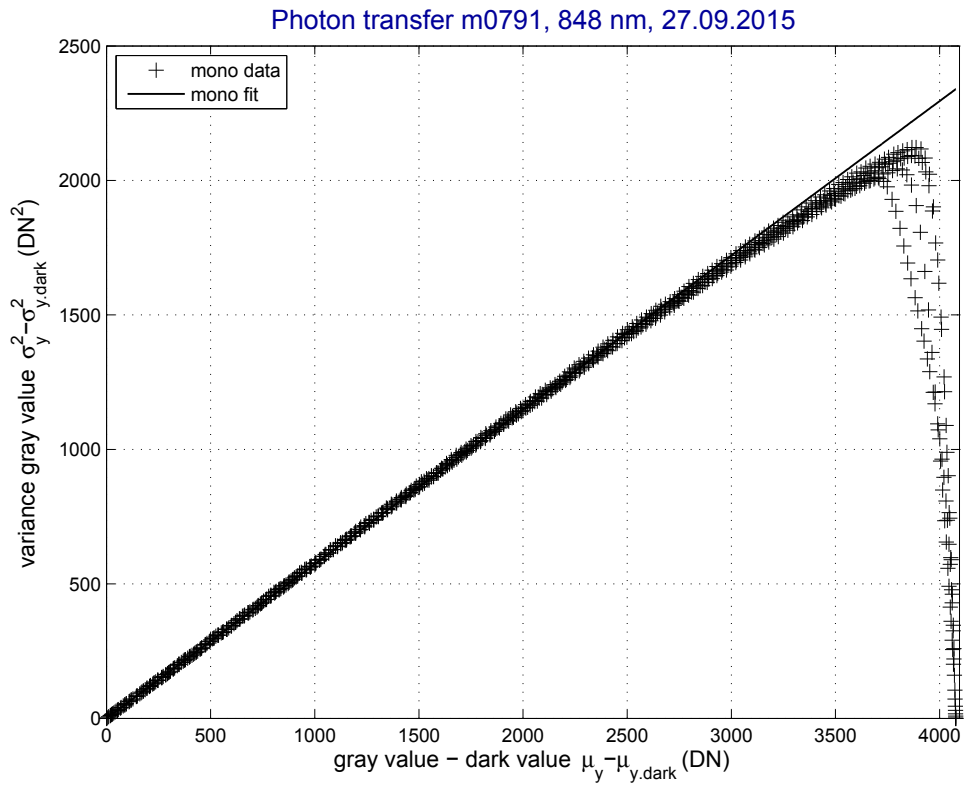
Saturation %	μ_y DN	σ_y DN	s_y DN	$\sigma_{\text{y.res}}$ DN	$s_{\text{y.corr}}$ DN	$s_{\text{y.corr}}$ %	$s_{\text{y.corr}}/s_y$ %
0	17.33	3.95	1.46	0.17	0.00	0.00	0.00
10	397.19	15.31	14.29	0.68	0.95	0.25	6.67
20	783.83	21.40	28.46	0.95	1.45	0.19	5.10
30	1170.46	26.05	42.36	1.15	1.64	0.14	3.86
40	1543.60	29.82	55.89	1.32	1.88	0.12	3.37
50	1924.92	33.28	69.50	1.47	0.01	0.00	0.01
60	2308.99	36.34	82.68	1.61	2.67	0.12	3.23
70	2675.00	38.92	95.32	1.72	3.35	0.12	3.52
80	3059.32	41.46	108.71	1.83	4.08	0.13	3.75
90	3446.88	43.70	121.43	1.93	5.60	0.16	4.61
100	3811.53	45.34	133.25	2.00	7.65	0.20	5.74

Comparative Evaluation with all Colors

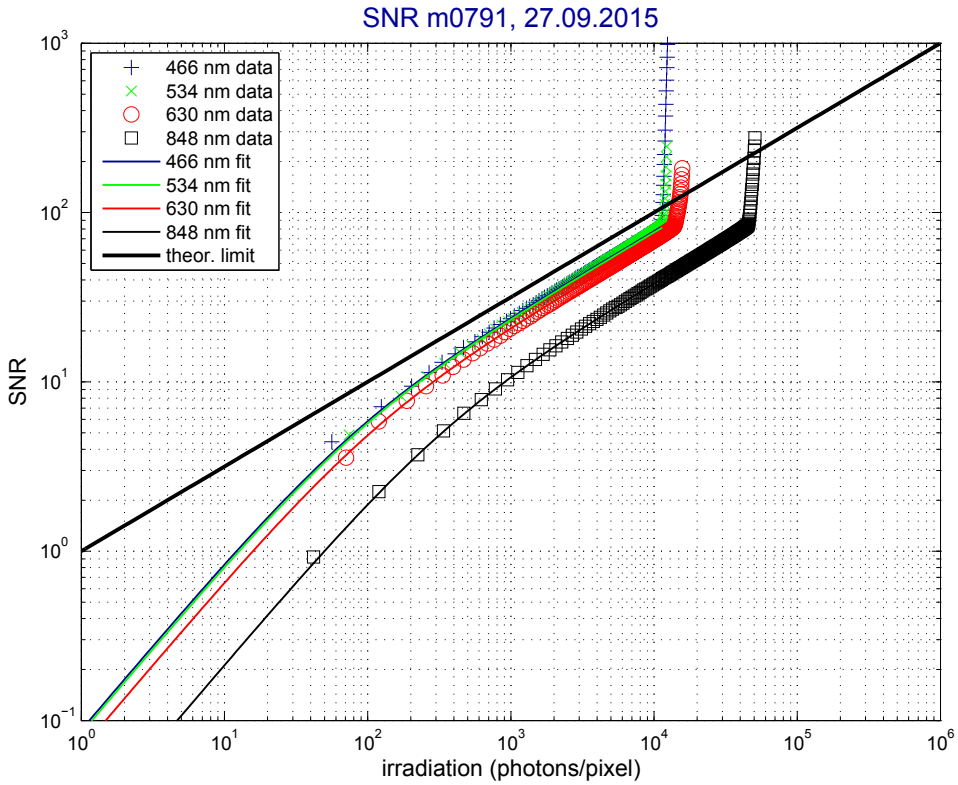
This whole section is in extension to the EMVA 1288 standard.



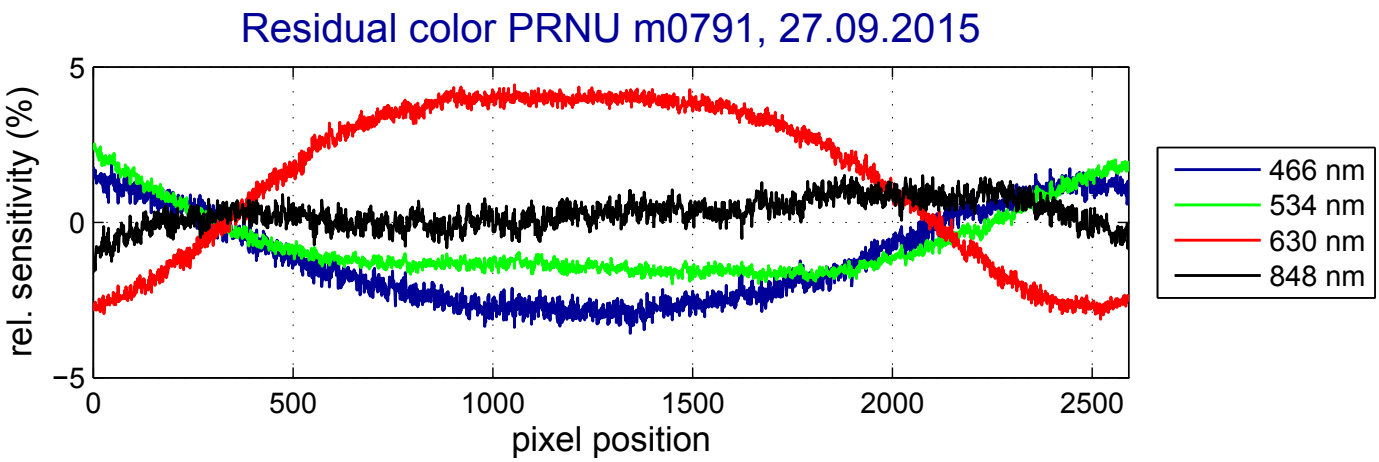
Comparative characteristic curve for selected colors/channels as indicated in the legend.



Comparative photon transfer curve for all measured color/channel combinations.

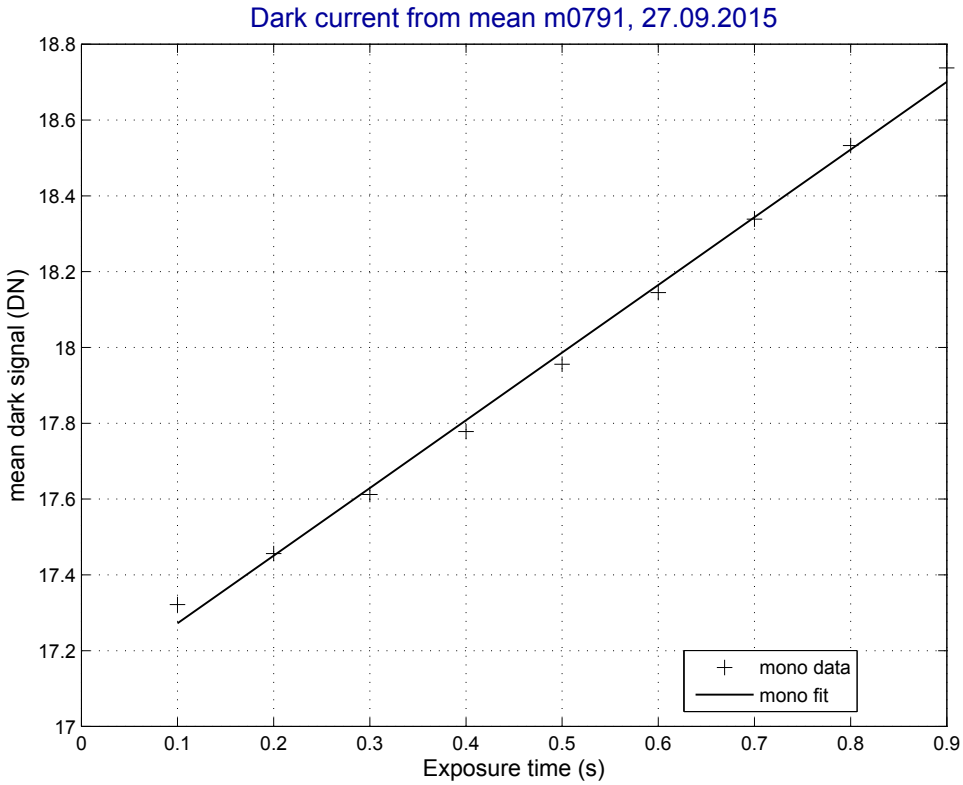


Comparative double-logarithmic SNR curve for selected colors/channels as indicated in the legend.

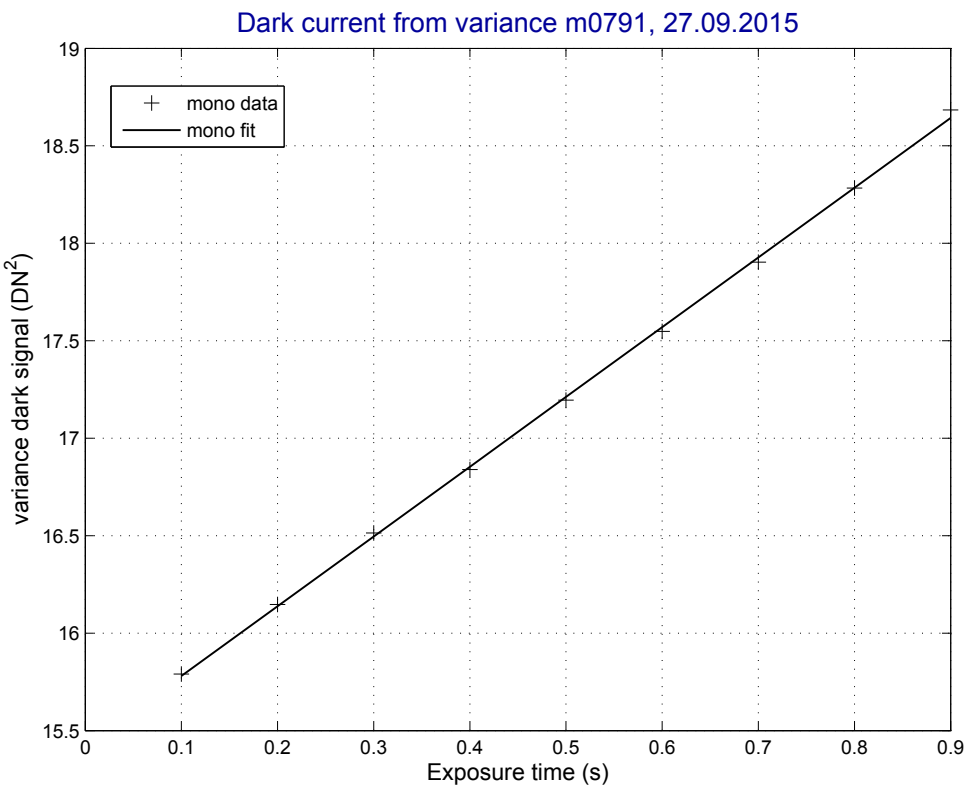


Color dependency of PRNU: profile of middle row of sensor, shown as deviation from PRNU averaged over all measured colors.

Dark Current

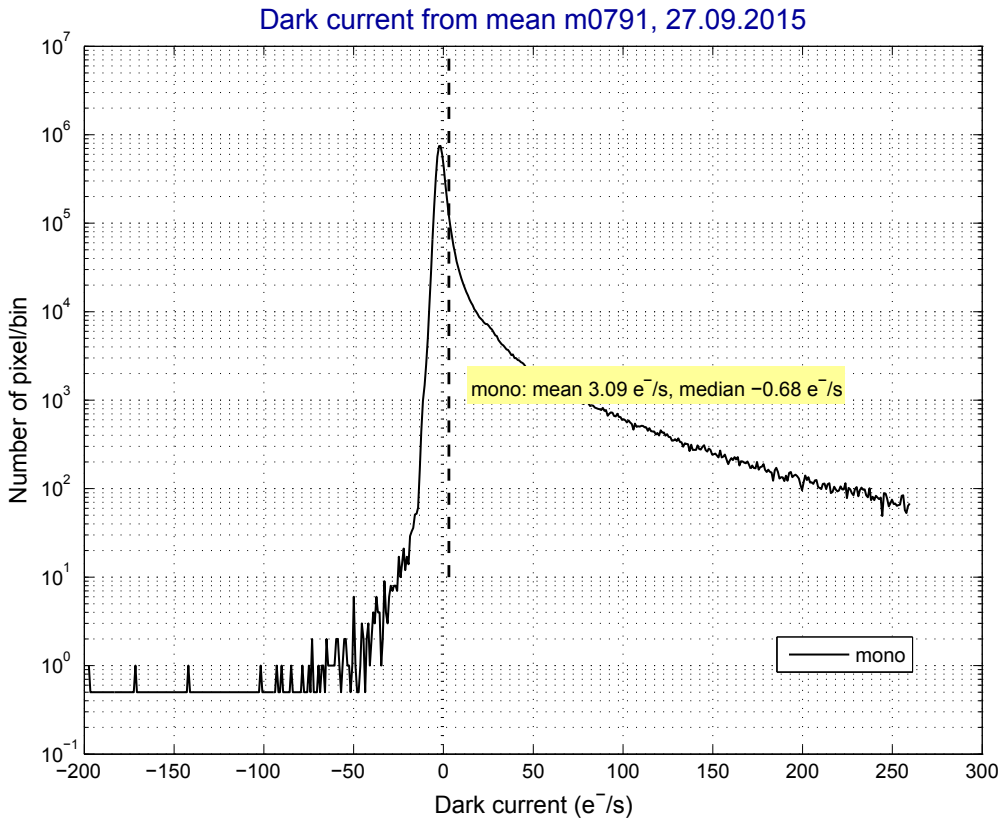


Mean of dark signal versus exposure time.

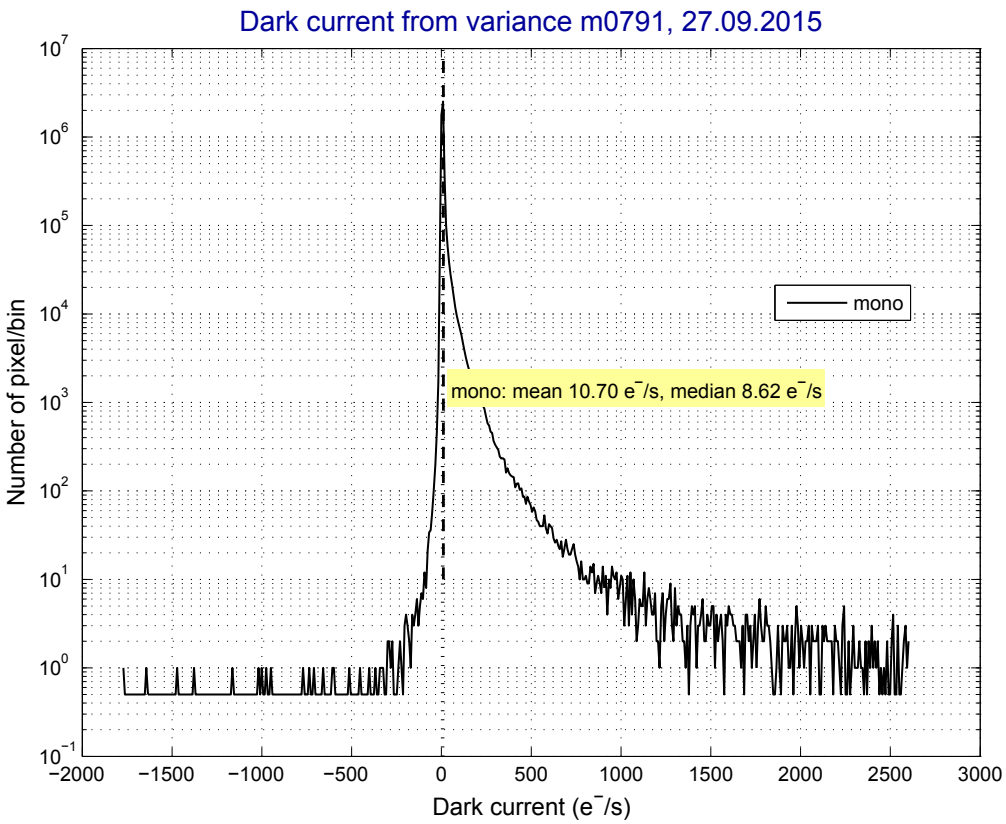


Variance of dark signal versus exposure time.

Spatial variation of dark current (extension to EMVA 1288)



Logarithmic histogram of spatial distribution of dark current in e /s from mean values



Logarithmic histogram of spatial distribution of dark current in e /s from variance

Comments