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# **OSIRIS**

**Optical, Spectroscopic, and Infrared Remote Imaging System**

## **OSIRIS camera linearity and saturation level**

RO-RIS-MPAE-TN-078

Issue: 1

Revision: b

11 November 2020

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16:54:00 +01'00'

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## Document Change Record

Iss./Rev.	Date / Author	Pages affected	Description
D / -	10/05/2015 G. Kovacs	all	first draft
1 / -	29/06/2015 G. Kovacs	all	first release
1 / a	22/2/2017 G. Kovacs	Sec. 3	Section added
1 / b	11 Nov 2020 C. Güttler	Sect. 2.2, 2.3, 3	Improved linearity assessment Updated linearity and saturation level for WAC



## Table of contents

1	General aspects.....	5
1.1	Scope .....	5
1.2	Applicable Documents .....	5
1.3	Reference Documents .....	5
2	Camera response linearity .....	6
2.1	Evaluation method.....	6
2.2	Re-Evaluation and Refinement .....	9
2.3	Results .....	9
3	Calibration files used by OsiCalliope.....	10

## List of Figures

Figure 1.	NAC linearity.....	8
Figure 2.	WAC linearity.....	8
Figure 3.	NAC (left) and WAC (right) linearity after calibration.....	9

## List of Tables

Table 1	Image statistics .....	7
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## 1 General aspects

### 1.1 Scope

This document describes the methods and results of the OSIRIS camera linearity analysis. The examination was carried out on the OSIRIS flight model Narrow Angle and Wide Angle Cameras to provide the following data for the calibration pipeline:

- saturation level of the CCD in DN units
- non-linearity level of the CCD in DN units
- general linearity performance of the camera system
- default shutter correction value for 0 ms exposure

The analysis is based on Vega and internal calibration lamp images.

### 1.2 Applicable Documents

no.	document name	document number, Iss./Rev.

### 1.3 Reference Documents

no.	document name	document number, Iss./Rev.
RD1	OSIRIS user manual	RO-RIS-MPAE-UM-004, D/s
RD2	OSIRIS Calibration Report	RO-RIS-MPAE-RP-147, 1/b
RD3	OSIRIS calibration pipeline OsiCalliope	RO-RIS-MPAE-MA-007, 1/-



## 2 Camera response linearity

The linearity analysis is based on the linearity observation sequences of the NAC and WAC systems, during the CG comet approach and escort phases of the Rosetta spacecraft. These sequences provided images of standard calibration stars (such as Vega) with several different commanded exposure times, from low exposure to full saturation.

The OSIRIS cameras utilize high quality CCDs, with full well capacity around 120,000 electrons. The readout electronics are adjusted to saturate the CCD, at A/D converter readouts well below the 65,536 limit. This results in different saturation DN values for the NAC and the WAC system.

### 2.1 Evaluation method

The Vega images were processed by the following method:

- The image statistics were calculated for the full window area of each image: average, std. dev., median, 1\_sigma\_clip\_avg (average after sigma clipping), sum\_DN (full DN content), see Table 1.
- The background was estimated by the sigma clip average
- The maximum pixel DN value determined
- The sum\_DN of an 11x11 pixel area around the star image was calculated after removing the background (Vega\_DN).
- Linear fit was applied over the exposure times, and the Vega\_DN. The deviation from the linear fit was calculated; see Figure 1. NAC linearity and Figure 2. WAC linearity.

**Table 1 Image statistics**

File	N pix	Avg	S_Dev	Median	Avg_1S	N pix	Sum	Max_pix	T_exp	NAC Vega_Dn	Linear_DN	delta%
NAC_2014-12-22T13.44.00.133Z_ID10_1397549000_F82	65536	2.38E+02	2.75E+01	237	2.37E+02	121	4.68470E+04	3714	0.100	18142.53	18350.9135	-1.15
NAC_2014-12-22T13.44.09.573Z_ID10_1397549100_F82	65536	2.38E+02	4.02E+01	237	2.38E+02	121	5.70270E+04	5397	0.150	28285.99	27915.8638	1.31
NAC_2014-12-22T13.44.18.583Z_ID10_1397549200_F82	65536	2.38E+02	5.27E+01	237	2.38E+02	121	6.62440E+04	8166	0.200	37497.67	37480.814	0.04
NAC_2014-12-22T13.44.29.543Z_ID10_1397549300_F82	65536	2.38E+02	8.12E+01	237	2.37E+02	121	8.54550E+04	13708	0.300	56717.62	56610.7145	0.19
NAC_2014-12-22T13.44.38.593Z_ID10_1397549400_F82	65536	2.39E+02	1.10E+02	237	2.38E+02	121	1.04013E+05	22352	0.400	75259.41	75740.615	-0.64
NAC_2014-12-22T13.44.49.573Z_ID10_1397549500_F82	65536	2.39E+02	1.63E+02	237	2.38E+02	121	1.43162E+05	31068	0.600	114406.11	114000.416	0.35
NAC_2014-12-22T13.44.58.604Z_ID10_1397549600_F82	65536	2.40E+02	2.13E+02	237	2.38E+02	121	1.80577E+05	35928	0.800	151815.54	152260.217	-0.29
NAC_2014-12-22T13.45.09.589Z_ID10_1397549700_F82	65536	2.41E+02	2.66E+02	237	2.38E+02	121	2.19521E+05	46348	1.000	190754.70	190520.018	0.12
NAC_2014-12-22T13.45.18.609Z_ID10_1397549800_F82	65536	2.42E+02	3.67E+02	238	2.38E+02	121	3.02985E+05	56664	1.500	274199.10	286169.521	-4.37
NAC_2014-12-22T13.45.29.569Z_ID10_1397549900_F82	65536	2.43E+02	4.22E+02	238	2.38E+02	121	3.69626E+05	56532	2.000	340839.37	381819.023	-12.02
NAC_2014-12-22T13.45.38.579Z_ID10_1397549000_F82	65536	2.46E+02	4.96E+02	238	2.39E+02	121	4.62951E+05	56680	3.000	434023.41	573118.028	-32.05
NAC_2014-12-22T13.45.49.560Z_ID10_1397549100_F82	65536	2.47E+02	6.31E+02	237	2.38E+02	121	6.70050E+05	56724	6.000	641284.31	1147015.04	-78.86
NAC_2014-12-22T13.45.58.760Z_ID10_1397549200_F82	65536	2.53E+02	7.54E+02	238	2.40E+02	121	9.14814E+05	56988	12.000	88583.123	2294809.07	-159.06
File	N pix	Avg	S_Dev	Median	Avg_1S	N pix	Sum	Max_pix	T_exp	WAC Vega_Dn		delta%
WAC_2014-12-22T13.46.18.433Z_ID10_1397549400_F12	16384	2.44E+02	2.65E+02	238	2.39E+02	121	1.17677E+05	20404	0.080	88791.88	88949.0934	-0.17706
WAC_2014-12-22T13.46.28.446Z_ID10_1397549500_F12	16384	2.46E+02	3.31E+02	240	2.40E+02	121	1.41365E+05	21996	0.100	112338.07	112181.714	0.139181
WAC_2014-12-22T13.46.37.548Z_ID10_1397549600_F12	16384	2.51E+02	5.00E+02	240	2.41E+02	121	1.99451E+05	33076	0.150	170327.87	170263.266	0.037931
WAC_2014-12-22T13.46.48.485Z_ID10_1397549700_F12	16384	2.55E+02	6.74E+02	241	2.41E+02	121	2.57501E+05	48048	0.200	228281.07	228344.819	-0.02792
WAC_2014-12-22T13.46.57.688Z_ID10_1397549800_F12	16384	2.60E+02	7.75E+02	242	2.43E+02	121	3.15100E+05	49968	0.300	285703.78	344507.923	-20.5822
WAC_2014-12-22T13.47.08.460Z_ID10_1397549900_F12	16384	2.70E+02	8.94E+02	246	2.47E+02	121	4.29722E+05	49968	0.600	399860.29	692997.236	-73.3098
WAC_2014-12-22T13.47.17.508Z_ID10_1397549000_F12	16384	2.86E+02	1.05E+03	252	2.54E+02	121	5.59771E+05	49984	1.000	528978.68	1157649.65	-118.846
WAC_2014-12-22T13.47.28.471Z_ID10_1397549100_F12	16384	3.16E+02	1.36E+03	267	2.71E+02	121	7.98686E+05	5016	2.000	765862.21	2319280.7	-202.833

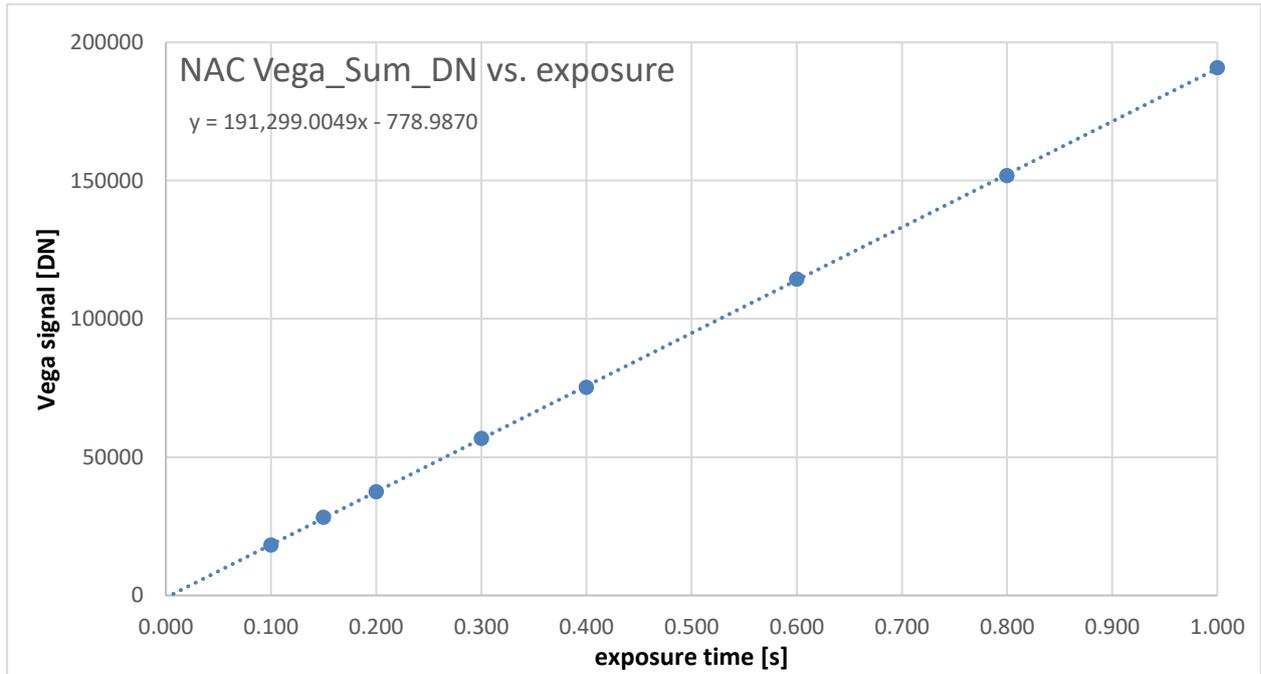


Figure 1. NAC linearity.

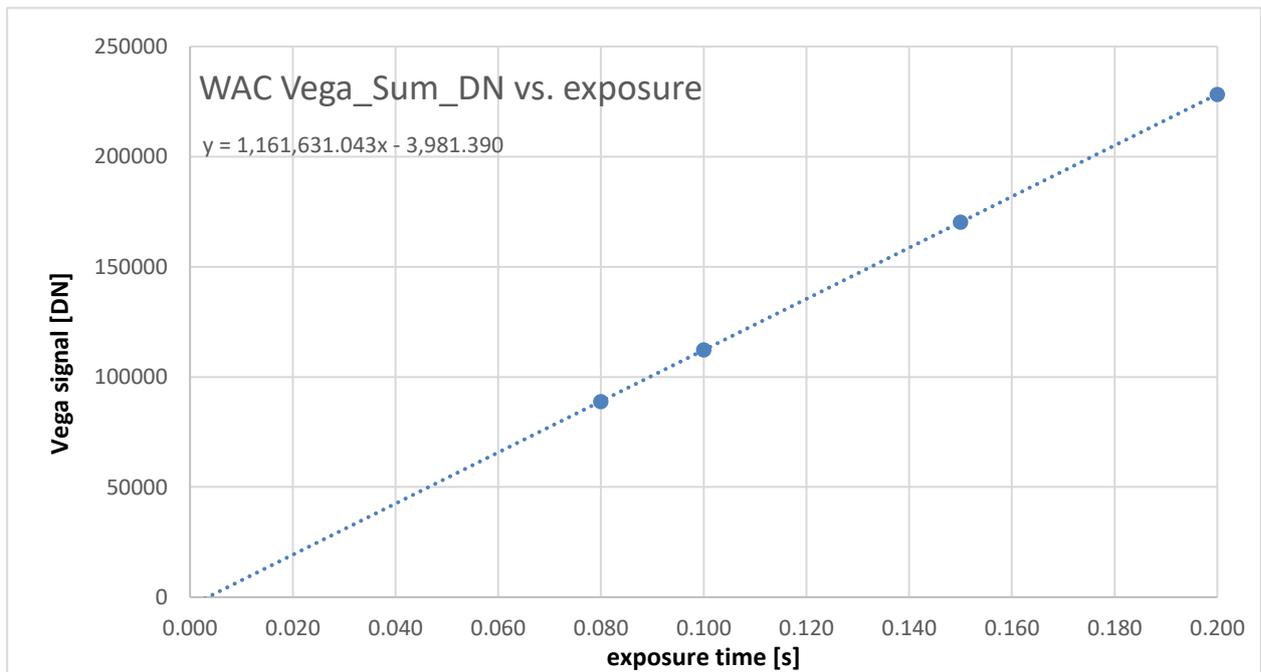


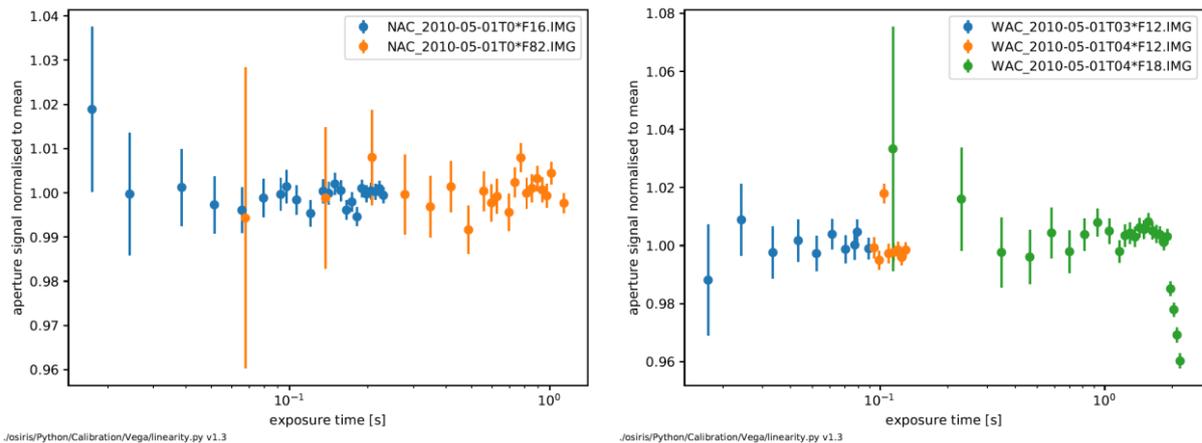
Figure 2. WAC linearity.



## 2.2 Re-Evaluation and Refinement

In the process of re-assessing the abs-cal factors in 2020, a refined method for Vega aperture photometry was developed. In this process, it also became clear that Vega images acquired with hardware windowing will show a larger error in the aperture signal due to coherent noise pattern in the background.

A sequence in May 2010 dedicated to linearity measurements was identified as the only linearity sequence without hardware windowing. From the calibrated images, divided by their abs-cal factors, the images in DN/s units were analysed for the Vega signal and their error (propagated from photon shot noise, background, and readout noise). The signal was normalised to the average per filter and plotted in Figure 3. The file mask in the legend of the figure defines the specific images used for this study. Images showing saturation in the quality map are filtered out.



**Figure 3. NAC (left) and WAC (right) linearity after calibration.**

Since these images are exposure time corrected, the signal shall be constant and invariant of exposure time. In this representation, deviations in from the expected mean show more prominently as compared to signal in DN in Figure 1 and Figure 2.

The Vega signal for the NAC at the smallest exposure time is slightly elevated with respect to the mean, which could theoretically be explained by a small overcorrection of the exposure time (2% corresponds to 0.35 ms error at 17.4 ms exposure time). However, the offset is within the error bar and the second data point does not support this. In conclusion, there is no indication for deviations larger than  $\sim 0.1$  ms, which is small compared to the minimum exposure time for scientific observation at comet 67P of 50 ms.

Also for the WAC, there is no argument for a trend. The orange outlier data point is explained by cosmic that is too close to the star to be filtered out.

This study also showed that Vega peak signals above 47,400 DN for the WAC deviate from linearity, as can be observed in the green symbols to the right in Figure 3. These are the only images that show indication of non-linearity not only in this sequence but over all OSIRIS Vega images acquired with software windowing. Based on this finding, the linearity and saturation level for the WAC was lowered from 48,000 to 47,400 DN with the release of issue 1, revision b of this document.

## 2.3 Results

Based on the Vega images, the linearity threshold levels are:



NON\_LIN\_LEVEL\_NAC = 54000 DN

NON\_LIN\_LEVEL\_WAC = 47400 DN

Although the pixels still collect electrons beyond the linearity level, the acquisition rate is poorly known and also pixel dependant. We therefore set the saturation levels to the same values:

SAT\_LEVEL\_NAC = 54000 DN

SAT\_LEVEL\_WAC = 47400 DN

### **3 Calibration files used by OsiCalliope**

The saturation and non-linearity levels are stored in:

- OSICALLIOPE\_V09.TXT

Previous versions:

- Until OSICALLIOPE\_V08.TXT levels from RO-RIS-MPAE-TN-078 1/a