OSIRIS

Optical, Spectroscopic, and Infrared Remote Imaging System

OSIRIS Camera Solar Stray Light

RO-RIS-MPAE-TN-087

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Table of contents

1 General aspects 5
1.1 Scope 5
1.2 Reference Documents 5
1.3 Acronyms and Abbreviations 5
2 Solar stray-light analysis 6
2.1 Evaluation method 6
2.2 Results 7
3 Extrapolation to other Solar Elongations and Filters 9
4 Calibration files used by OsiCalliope 9

List of Figures

Figure 1: NAC F22 (left) and WAC 12 (right) solar stray-light pattern at 60° solar elongation (both represented in Rosetta standard orientation, see RD3). 7
Figure 2: Normalized average DN/s vs. solar elongation. Data from Table 3. 8
Figure 3: Original OSIRIS level 3 (CODMAC L4) image (left; WAC_2015-08-28T19.27.59.318Z _ID30_1397549002_F21) compared to the corrected OSIRIS level 3C (CODMAC L4) image (right). The solar elongation is 40° and both images are scaled from 0 to 10^{-6} W / m^2 sr nm (both represented in Rosetta standard orientation, see RD3). 8

List of Tables

Table 1: Stray-light observation campaigns in flight. 6
Table 2: Images used for stray-light computations. 6
Table 3: Average stray-light-signal DN/s, normalized to 1 au. 7

1 General aspects

1.1 Scope

This document describes the methods and results of the OSIRIS camera solar stray-light analysis. The examination was carried out on the OSIRIS FM Narrow Angle and Wide Angle Cameras to provide the following data for the calibration pipeline:

- Reference images for stray-light calibration, based on solar stray-light observation sequences with specific filter combinations
- Spectral scaling parameters, for filter combinations without dedicated stray-light sequence

The analysis is based on inflight solar stray-light tests.

1.2 Reference Documents

no.	document name	document number, Iss./Rev.
RD1	OSIRIS user manual	RO-RIS-MPAE-MA-004, D/s
RD2	OSIRIS calibration pipeline OsiCalliope	RO-RIS-MPAE-MA-007, 1/c
RD3	Rosetta-OSIRIS To Planetary Science Archive Interface Control Document	RO-RIS-MPAE-ID-015, 4/b

1.3 Acronyms and Abbreviations

OSIRIS	Optical, Spectroscopic, and Infrared Remote Imaging System
NAC	Narrow Angle Camera
WAC	Wide Angle Camera
FM	Flight Model
CG	Comet 67P/Churyumov-Gerasimenko
DN	Digital numbers, i.e., counts on the CCD

2 Solar stray-light analysis

The solar stray-light analysis is based on the observation sequences of the NAC and WAC systems, during the CG comet approach and escort phases of the Rosetta spacecraft. These sequences provided images with different solar elongation angles and exposure times.

Table 1: Stray-light observation campaigns in flight.

Observation Name	Date	Cameras & Filters	Solar Elongations	Comment
STP003_CALIB_STRAYLIGHT	2014-05-11	N22 W12, W21	20°-90°	< 30° images saturated
STP102_STRAYLIGHT_001	2016-04-01	N22, N24 W12, W21	30°-100°	< 50° images saturated biased by CG and dust
STP107_STRAYLIGHT_001	2016-05-09	N22, N24 W12, W21	30°-70°	biased by CG and dust

Wherever it was possible, the “STP003_CALIB_STRAYLIGHT” sequence was used in the analysis, as the best sequence with no cometary dust particles and coma effect. However, due to overexposure and missing filters, this was not always possible. The filenames of the specific images used for this study are listed in the following table.

Table 2: Images used for stray-light computations.

Solar Elong.	NAC F22	NAC F24	WAC F12	WAC F21
30°	NAC_2016-05-09T20.55.15.523Z _ID10_1397549000_F22	NAC_2016-05-09T20.55.21.383Z _ID10_1397549001_F24	WAC_2014-05-11T16.27.46.407Z _ID10_1397549000_F12	WAC_2014-05-11T16.24.55.488Z _ID10_1397549000_F21
40°	NAC_2014-05-11T16.39.46.647Z _ID10_1397549000_F22	NAC_2016-05-09T20.45.29.699Z _ID10_1397549001_F24	WAC_2014-05-11T16.42.46.429Z _ID10_1397549000_F12	WAC_2014-05-11T16.39.55.435Z _ID10_1397549000_F21
50°	NAC_2014-05-11T16.54.46.572Z _ID10_1397549000_F22	NAC_2016-05-09T20.34.35.734Z _ID10_1397549001_F24	WAC_2014-05-11T16.57.46.433Z _ID10_1397549000_F12	WAC_2014-05-11T16.54.55.434Z _ID10_1397549000_F21
60°	NAC_2014-05-11T17.09.46.559Z _ID10_1397549000_F22	NAC_2016-05-09T20.21.42.043Z _ID10_1397549001_F24	WAC_2014-05-11T17.12.46.428Z _ID10_1397549000_F12	WAC_2014-05-11T17.09.56.392Z _ID10_1397549000_F21
70°	NAC_2014-05-11T17.24.46.570Z _ID10_1397549000_F22	NAC_2016-04-01T17.30.57.702Z _ID10_1397549001_F24	WAC_2014-05-11T17.27.46.409Z _ID10_1397549000_F12	WAC_2014-05-11T17.24.55.531Z _ID10_1397549000_F21
80°	NAC_2014-05-11T17.39.46.546Z _ID10_1397549000_F22	NAC_2016-04-01T17.55.21.700Z _ID10_1397549001_F24	WAC_2014-05-11T17.42.46.416Z _ID10_1397549000_F12	WAC_2014-05-11T17.39.56.395Z _ID10_1397549000_F21
90°	NAC_2014-05-11T17.54.46.547Z _ID10_1397549000_F22	NAC_2016-04-01T18.19.45.701Z _ID10_1397549001_F24	WAC_2014-05-11T17.57.46.405Z _ID10_1397549000_F12	WAC_2014-05-11T17.54.55.504Z _ID10_1397549000_F21

2.1 Evaluation method

The solar stray-light images were processed by the following method:

- The image statistics were calculated for the full window area of each image: average, standard deviation, median, total flux
- 5x5 median filtering to remove cosmics and other artefacts
- Un-bin images to full size (2048x2048)
- ADC offset correction
- Bias removal
- Flat field correction
- Bad pixel removal
- Normalization to 1 s exposure time

- Normalization to 1 au solar distance

The processed images – with increasing solar elongation – were assembled into a single PDS data product for each filter combination. This is stored as the stray-light reference image in the calibration database (see Sect. 4). It contains seven objects (image layers) of solar elongation and the relevant ancillary data in the attached header.

2.2 Results

Examples for the stray-light pattern after the processing steps described in Sect. 2.1 are shown below. The patterns are different for NAC and WAC as can be seen in Figure 1. Also the pattern changes with solar elongation, in particular for the NAC.

To get a feeling for the overall stray-light contribution, Table 3 provides an average solar stray-light signal over the full image. A graphic representation of the same data is provided in Figure 2.

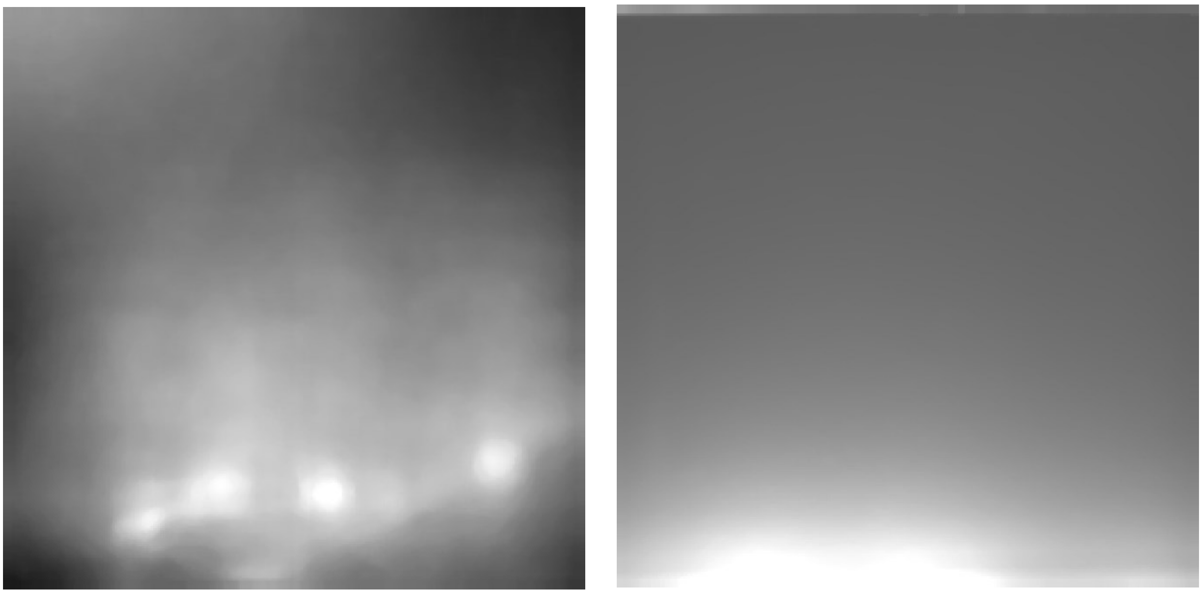

Figure 1: NAC F22 (left) and WAC 12 (right) solar stray-light pattern at 60° solar elongation (both represented in Rosetta standard orientation, see RD3).

Table 3: Average stray-light-signal DN/s, normalized to 1 au.

Solar elongation	NAC F22	NAC F24	WAC F12	WAC F21
30°	829	492	1227	481.5
40°	112	67.9	635.7	251.5
50°	70	45.9	360.7	143.9
60°	52	36.1	216.9	86.12
70°	1.5	1.17	136.7	54.7
80°	1.52	1.17	18.36	7.17
90°	0	0	0	0

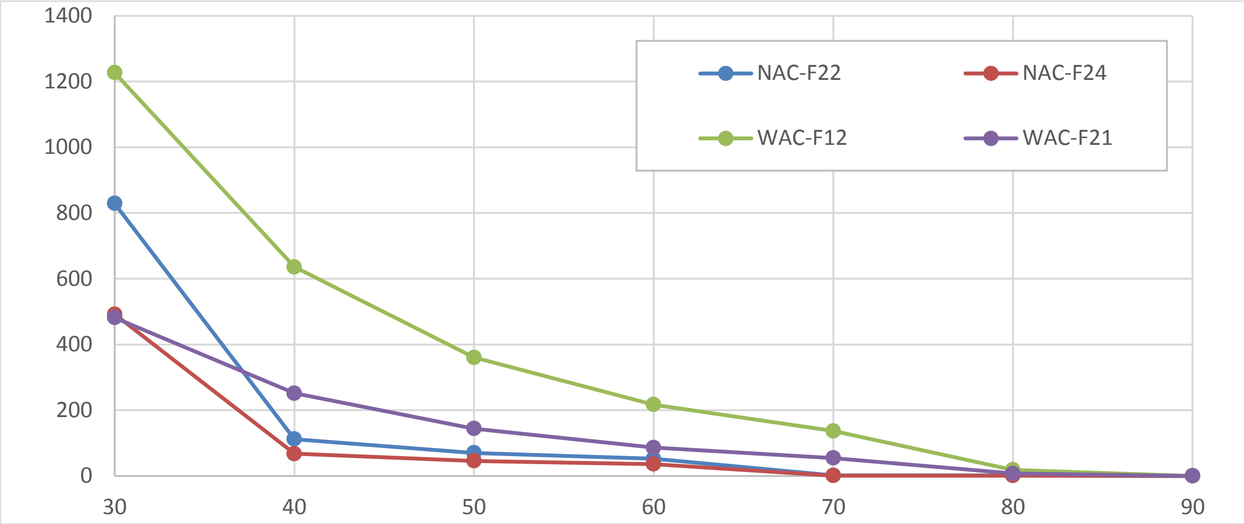

Figure 2: Normalized average DN/s vs. solar elongation. Data from Table 3.

An example of an original image (OSIRIS level 3; CODMAC L4) compared to its stray light corrected image (OSIRIS level 3C; CODMAC L4) is presented in Figure 3. The image was taken at 40° solar elongation (wrt. the image centre). Small features like screw heads at the upper and lower edges are not fully corrected but the overall image is free of solar stray light. In this particular example, the solar stray light component was 90% of the total signal and 10% remain after correction.

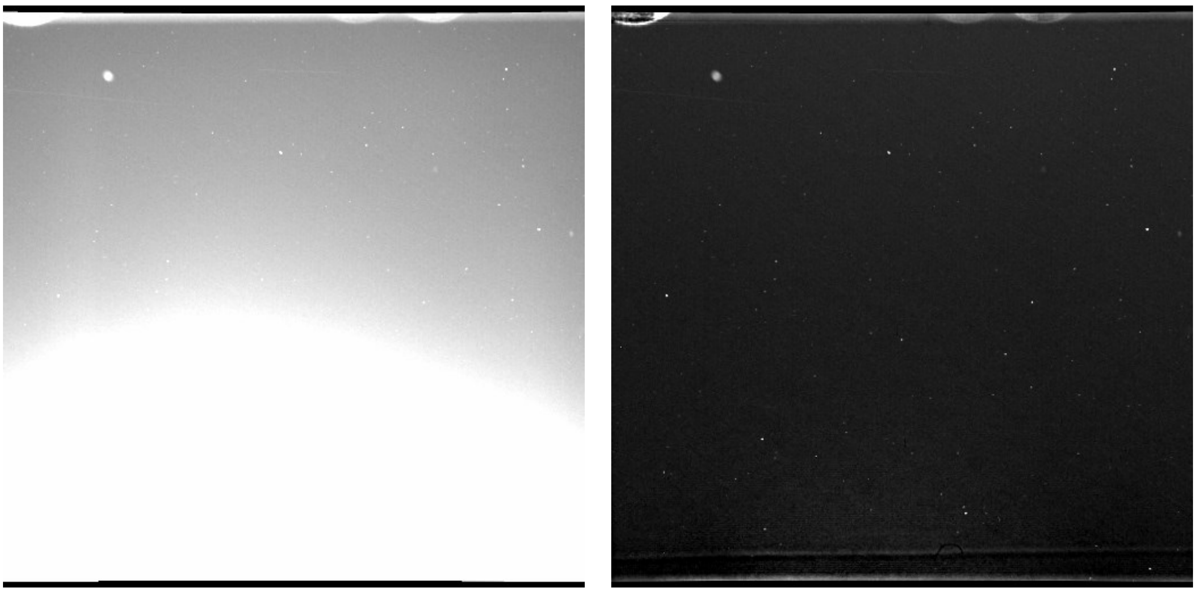

Figure 3: Original OSIRIS level 3 (CODMAC L4) image (left; WAC_2015-08-28T19.27.59.318Z _ID30_1397549002_F21) compared to the corrected OSIRIS level 3C (CODMAC L4) image (right). The solar elongation is 40° and both images are scaled from 0 to 10^{-6} W / m^2 sr nm (both represented in Rosetta standard orientation, see RD3).

3 Extrapolation to other Solar Elongations and Filters

The actual stray-light contribution of an image at a given solar elongation is calculated by parabolic interpolation of the reference image planes, pixel by pixel. For filter combinations where no reference image is available (no stray-light calibration observations), the closest wavelength filter combination is used with relative solar flux and sensitivity scaling. This is based on the OsiCalliope database absolute calibration factors, and solar flux values. The calibration algorithm is further explained in the OsiCalliope manual [RD2].

4 Calibration files used by OsiCalliope

The calibration files used by OsiCalliope to calibrate OSIRIS images are:

- NAC_FM_SOL_STL_22_V01.IMG
- NAC_FM_SOL_STL_24_V01.IMG
- WAC_FM_SOL_STL_12_V01.IMG
- WAC_FM_SOL_STL_21_V01.IMG

The files are included in each public delivery of OSIRIS data to PSA. The location is specified in the OSIRIS EAICD [RD3].