RADIOMETRIC CROSS-CALIBRATION OF THE ROSETTA NAVIGATION CAMERA. T. Statella[1] and

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Introduction: The Rosetta spacecraft, whose target was the 67P/Churyumov-Gerasimenko comet, carried an optical broad-band camera used for navigational purposes, named NavCam. Accurate geometric calibration for that instrument was available, but its radiometric properties characterization was not addressed. In order to allow for the NavCam images to be used for comet photometric properties retrieval, a proper radiometric calibration should take place. In this abstract we show the cross-calibration of the NavCam based on images acquired by the OSIRIS instrument, a scientific camera system onboard Rosetta.

Cross-Calibration of the NavCam: We have considered a disk-integrated methodology using the average comet nucleus signal in the radiometric calibration calculations. For that purpose, we extracted the Digital Number (DN) values of pixels laying in the comet nucleus with a binary mask for marking the nucleus limb.

The NavCam images used for this study have been acquired by Rosetta on 2014-08-01 in the time range from t=12:07:17h to t=21:07:17h. The data are available in ESA's Planetary Science Archive (PSA) as un-calibrated "Level 2" images in PDS3 format [1]. The set of eight available images is presented in Figure 1, which displays the original images, a zoomed inset of the comet nucleus (at the bottom left corner) and the binary mask used to segment the pixels of the nucleus (at the bottom right corner).
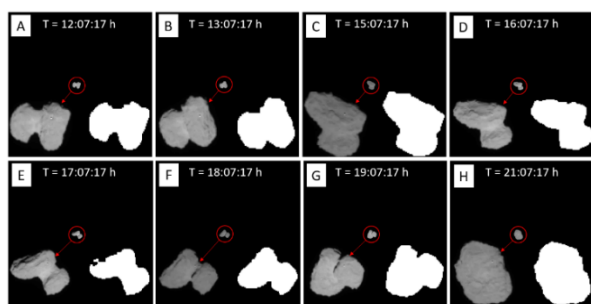

Figure 1. NavCam images acquired on 2014-08-01. Credits: *ESA/Rosetta/NAVCAM. Archive dataset: [1].*

Information about these images is given in Table 1. The integration time for all scenes was 1.0 s. As a pre-processing step, we have subtracted a bias field from each scene in order to correct the detector offset. Next, we have converted the images from DN count numbers to DN per second (DN/s) by dividing them by the respective scene exposure time. Binary masks for the comet nucleus have been created by using Otsu's algorithm [2] for automatic thresholding [3].

Table 1. Information on NAVCAM images.

ID	Average signal [DN/s]	σ [DN/s]
ROS_CAM1_20140801T120717F	1876	±168
ROS_CAM1_20140801T130717F	1864	±153
ROS_CAM1_20140801T150717F	1764	±162
ROS_CAM1_20140801T160717F	1719	±225
ROS_CAM1_20140801T170717F	1759	±242
ROS_CAM1_20140801T180717F	1791	±210
ROS_CAM1_20140801T190717F	1787	±177
ROS_CAM1_20140801T210717F	1733	±125

Next, morphological opening and closing transformations, which act as local adaptive filters, have been applied to the segmentation in order to filter out black and white isolated pixels caused by noise or artefacts during the acquisition process. Finally, a morphological erosion, which produces a shrinking effect on the brighter objects, has been applied to the masks for avoiding the influence of pixels in the fringe of the nucleus when calculating the average nucleus Digital Number per second (DN/s).

For the comparison we used OSIRIS-NAC images acquired on 2014-08-01 from t=11:50:14.576h to t=20:44:43.524h, which were radiometrically calibrated as described by [4]. The calibrated images are available as "Level 3" datasets in the Planetary Science Archive [5]. There were 8 sets of OSIRIS images which are each composed of 7 scenes acquired in different filters: Blue, Green, Orange, Hydra, Red, Near Infrared (NIR) and Infrared (IR). The procedure to create the masks is the same as used for NavCam images.

For each of the sets of OSIRIS-NAC images, we fitted a third-degree polynomial to the radiance data points in the different filters in order to obtain the spectral radiance distribution $L_O(\lambda)$. Then, we computed the average spectral radiance L_N^* in the NavCam filter band with the NavCam spectral sensitivity curve $S_N(\lambda)$ as follows:

$$L_N^*(\lambda) = \frac{\int_\lambda L_O(\lambda)S_N(\lambda)\lambda d\lambda}{\int_\lambda S_N(\lambda)\lambda d\lambda} \tag{1}$$

In Figure 2 we show the average comet nucleus spectral radiance as a function of wavelength for the first set of images (OSIRIS at T = 11:50:15 h and NavCam

at $T = 12:07:17$ h). The circles represent the OSIRIS-NAC images whereas triangles represent the NavCam radiance calculated with equation (1) from the spectral radiance distribution derived from the calibrated OSIRIS-NAC images.
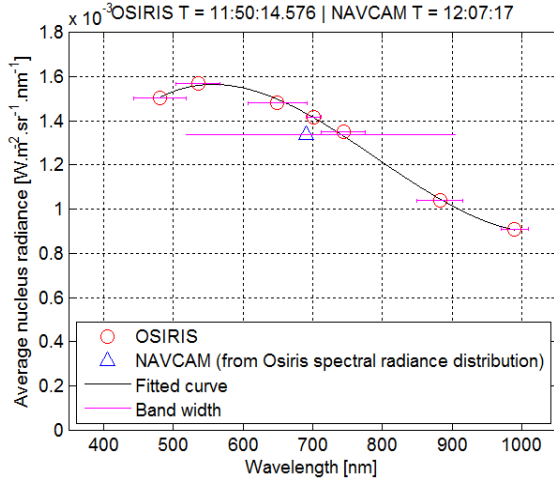

Figure 2. Average comet nucleus spectral radiance as a function of wavelength.

As a final step, the NavCam radiometric calibration factor *Cal* resulting from the cross-calibration exercise can be determined as the ratio of the average spectral radiance L_N^* calculated from equation (1) and the measured average come nucleus signal in DNs^{-1}:

$$Cal = \frac{L_N^*(\lambda)}{DN/s} \qquad (2)$$

Therefore, we have calculated a total of 8 candidates to calibration factors in Wm^{-2}sr^{-1}nm^{-1}/ (DNs^{-1}), one for each OSIRIS set. The average of those values resulted in the final radiometric calibration factor:

$$Cal = (7.14 \pm 0.07) \cdot 10^{-7} \frac{Wm^{-2}sr^{-1}nm^{-1}}{DNs^{-1}}. \qquad (3)$$

As these images were acquired in attenuated cover position (FOC_ATT) and HIGH gain, the estimated factor is suitable for that specific mode of operation.

Conclusion: We carried out a cross-calibration analysis based on OSIRIS-NAC data in order to radiometrically calibrate the *Rosetta* NavCam. The best data set identified for that purpose is a sequence of images acquired by both cameras on 2014 August 1 shortly before close encounter with the comet. The estimated radiometric factor was $(7.14 \pm 0.07) \cdot 10^{-7}$ in units of Wm^{-2}sr^{-1}nm^{-1}/ (DNs^{-1}), and it is suited for processing images acquired with the attenuation filter (FOC_ATT) and HIGH gain mode.

References: [1] Geiger B. and Barthelemy M., (2015) "ROSETTA ORBITER NAVCAM PRELANDING MTP006, RO-C-NAVCAM-2-PRL-MTP006-V1.0", ESA Planetary Science Archive and NASA Planetary Data System. [2] Otsu, N. (1979) *IEEE Trans. Sys., Man and Cyb., 9*, 62-66. [3] Statella T. and Geiger B. (2017) *MNRAS, 469*, S285-S294. [4] Tubiana C. et al. (2015) *A. and A., 583*, A46. [5] Gutierrez-Marques P. and the OSIRIS Team (2015), "ROSETTA ORBITER PRELANDING OSINAC 3 RDR DATA MTP 006 V1.0, RO-C-OSINAC-3-PRL-67PCHURYUMOV-M06-V1.0", ESA Planetary Science Archive and NASA Planetary Data System.