USE OF THE DAWN FLIGHT SPARE CAMERA AT APOPHIS? A. Nathues[1], T. Kleine[1], H. Sierks[1], M. Hoffmann[1], R. Sarkar[1], M. Coutelier[1], H. Rauer[2], J.B. Vincent[2], B. Gundlach[3], H. Hiesinger[3], C. Güttler[3], N. Schmedemann[3], J.H. Pasckert[3], D. Koschny[4]
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Introduction: The Framing Camera (FC) was the German contribution to NASA's Discovery Mission Dawn that was operational between 2007 and 2018. Two identical cameras were successfully flown to the large main belt asteroids (4) Vesta and (1) Ceres and returned more than 100,000 images, leading to a wealth of new information about both protoplanets.

Two spare FCs, still stored at the MPI for Solar System Research, are fully functional and flight-ready. One of these models could be used as an optional payload for ESA's potential RAMSES mission. The FC would complement the on-board Asteroid Framing Camera (AFC) by adding spectral information.

Framing Camera: The FC (Fig.1) [1] is equipped with a frame transfer CCD of 1024 x 1024 pixel, one clear, and seven color filters, covering the wavelength range between 0.4 and 1.0 µm. The relatively large field of view of 5.5° by 5.5° guaranties global mapping capabilities with a spatial resolution of 93.7 µrad/pixel. The FCs have been designed, manufactured, and tested by a German consortium consisting of MPS, DLR-PF, and IDA.

Fig. 1: *Dawn FC without MLI (Sierks et al. 2011).*

The scientific imagery of the Dawn FCs received their final calibration in 2019 [2]. We were successful in removing all remaining internal stray-light contamination of the camera and finally reached a relative uncertainty of the reflectance spectra ranging from ± 0.5 to ±1.0 % (±2% absolute), depending on the used filter.

Science: The high photometric accuracy of the Dawn FC enables an outstanding contrast in color mosaics/cubes (Figs. 2 to 4) and thus fostered a number of striking discoveries at Vesta and Ceres. Among these are the discovery of cryo-volcanism [3, 4] and organic-rich material on Ceres [5] as well as the detection of a nearly global layer of dark, primitive material on Vesta caused by one major impact event [6].

To date more than 150 peer-reviewed publications, based on Dawn FC data, were published by scientists from Europe and the US. Many of them were led by one of the participating German institutes/universities (MPS, DLR-PF, IfP, FU-Berlin).

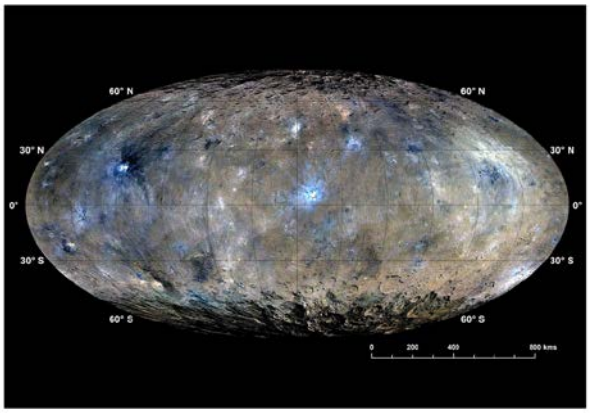

Fig. 2: *Ceres global color map (R = 0.96 µm, G = 0.75 µm and B = 0.44 µm) based on Dawn FC color data [7].*

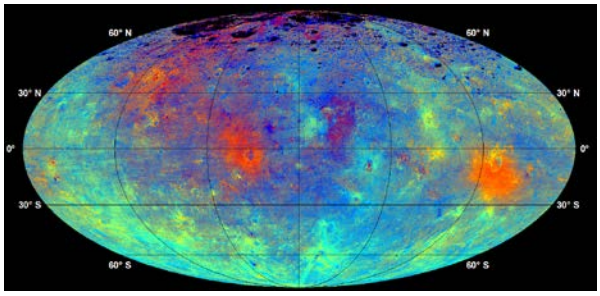

Fig. 3: *Vesta global color map in "Clementine Ratios" (Red = 0.75 µm/0.45 µm, Green = 0.75 µm/0.92 µm, and Blue 0.45 µm/0.75 µm) (©MPS).*

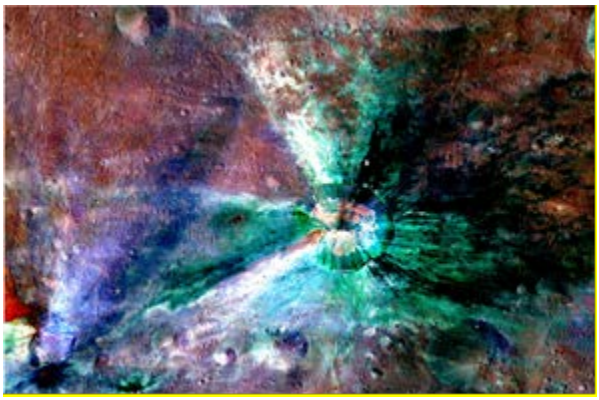

Fig. 4: *Vesta's crater Canuleia (Red = (550 µm*750 µm)/440 µm, Green = (650 µm* 650 µm)/550 µm, and Blue = (440 µm*750 µm)/650 µm) (©MPS).*

Apophis Science: The strength of the FC is its global color mapping capability. The color filters, originally selected for Vesta, are also well suited for the S-type Near-Earth Asteroid Apophis as Fig. 5 demonstrates. Apophis is expected to consist mainly of the minerals olivine and pyroxene, both showing a strong, wide 1-µm absorption feature that is largely covered by the FC. Slight differences, especially in the relative reflectance of the four filters covering the shape of the 1-µm absorption, are suited to discriminate between olivine and pyroxene dominated areas [8] or at least their variation across the target.

In addition, the spectral capability of the FC will be suited to identify pristine or less-weathered material, which probably gets exposed trough avalanches, caused by tidal forces during the Earth flyby.

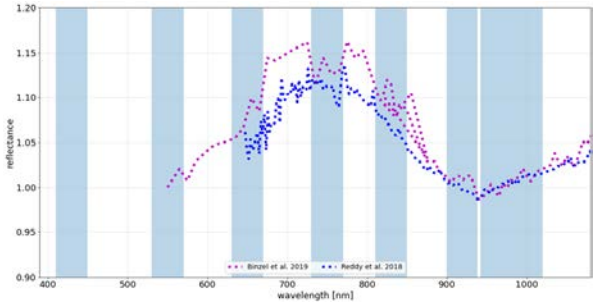

Fig. 5: *Reflectance spectra of Apophis obtained by ground-based telescopes. The seven FC color bands cover the shape of the 1-µm absorption band to a high degree.*

Besides color capabilities, the FC is useful to help to determine the physical parameters of Apophis, such as its ration periods, axis orientations, and shape [9]. Potential dust levitations, caused during Apophis' passage through the earth magnetic field, might also be identified.

FC for RAMSES:

Until today two flight-ready Framing Cameras are stored at MPS in a clean and safe environment. Due to their originally planned adoption to the Hera mission and the following extensive characterization, these are ready for a further mission.

Also, the ground support equipment required to operate the cameras is in place and ready for use. Since the design of the RAMSES spacecraft is practically identical to Hera, no significant adaptions of the FC are needed, reducing the costs of a FC re-use significantly.

Based on our long experience and expertise with the Dawn FC, the turnaround time of the data can be kept to a minimum, i.e. would be in the order of minutes for the raw data, and a few hours for the calibrated data.

Hence, we propose the use of one of the FCs for the RAMSES mission to Apophis.

References: [1] Sierks et al., SSR **163**, 263–327 (2011); [2] Kovacs et al., SSR **220**, #4 (2024); [3] Nathues et al., AJ **153**, 112 (2017) ; [4] Nathues et al., Nature Astronomy **4**, 794 – 801 (2020); [5] Pieters et al., M&PS **53**, 1983 – 1998 (2018); [6] Reddy et al., Science **336**, 700 – 704 (2011); [7] Nathues et al., Nature Comm. **13**, #927 (2022); [8] Nathues et al., Icarus **258,** 467 – 482 (2015); [9] Preusker et al., LPSC #1954 (2016)