CaSSIS: Overview of imaging in the first 9 months of the prime mission. N. Thomas[1], G. Cremonese[2], M. Almeida[1], M. Banaszkiewicz[3], J.N. Bapst[4], P. Becerra[1], J.C. Bridges[5], S. Byrne[4], S. Conway[6], V. Da Deppo[7], S. Debei[8], M.R. El-Maarry[9], A. Fennema[4], E. Hauber[10], R. Heyd[4], C.J. Hansen[11], A. Ivanov[12], L. Keszthelyi[13], R. Kirk[13], R. Kuzmin[14], A. Lucchetti[2], N. Mangold[6], C. Marriner[15], L. Marinangeli[16], M. Massironi[17], A.S. McEwen[4], C. Okubo[13], P. Orleanski[3], M. Pajola[2], A. Parker Bowen[5], M.R. Patel[15], J. Perry[4], A. Pommerol[1], R. Pozzobon[17], M.R. Read[1], P.-A. Tesson[3], L. Tornabene[18], S. Tulyakov[19], P. Wajer[3], P. Witek[3], J. Wray[20], and R. Ziethe[1*].
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Introduction: The ExoMars Trace Gas Orbiter (TGO) was launched on 14 March 2016 and entered Mars orbit on 19 October 2016. The spacecraft reached its primary science orbit (360 km x 420 km; inclination = 74°) on 9 April 2018. TGO carries a high-resolution colour and stereo camera system called the Colour and Stereo Surface Imaging System (CaSSIS). The objectives of CaSSIS are to (1) characterise sites on the Martian surface which have been identified as potential sources of trace gases, (2) investigate dynamic surface processes (e.g. sublimation, erosional processes, volcanism) which may help to constrain the atmospheric gas inventory, and (3) certify potential future landing sites by characterising local slopes (down to ~10 m).

The instrument capabilities include (1) acquisition of images at scales as small as 4.5 m/px, (2) production of images in 4 broad-band colours optimised for Mars photometry, (3) acquisition of a swath up to 9.5 km in width, and (4) acquisition of quasi-simultaneous stereo pairs over the full swath width for high res. digital terrain models. A full instrument description is provided in [1], and details about the ground calibration in [2]. Spectral-image simulations to assess the colour and spatial capabilities of CaSSIS are in [3], and the full payload of TGO is described in [4]. Finally, the operations approach for CaSSIS is found in a companion abstract [5].

Observations: CaSSIS has been acquiring data regularly since 28 April 2018. A planet-encircling dust event limited surface visibility between mid-June and the end of August 2018 with steady improvement in atmospheric transmission thereafter. Initially only targets along the ground-track could be acquired, but starting in November 2018, targeted observations began by rolling the spacecraft up to 5°. The number of acquisitions per day strongly depends on data rate and the imaging mode used, but typically 16 images per day are acquired of which roughly half are stereo pairs. TGO is not in a Sun-synchronous orbit and hence image mode choices are optimized to account for the specific lighting conditions. Between 8 Sept 2018 and 29 Dec 2018 alone, 2354 images were attempted (a stereo pair counts as 2) with a 90.5% completion rate. Image loss mostly results from two flight software errors that will be corrected by a flight software upload foreseen for the 1st quarter of 2019. A wavelet data compression scheme is available providing both lossless and lossy compression. Lossless compression currently averages a compression ratio of about 1.75:1. Lossy compression factors of up to 4 have been used during the first months of observation with no obvious loss in image quality.

Reduction: Images are reduced by a standard radiometric pipeline and converted into I/F. Previous efforts suggest that I/F values are in good agreement with MEx/OMEGA. Recent updates to the bias, flat field and straylight subtraction algorithms have improved the signal to noise ratio in all colours. Some effects of straylight can still be seen in low contrast data at specific geometries. Further algorithm improvements are to be expected. The geometric distortion and corrections have been derived allowing production of rectified images and stereo products. A pipeline is being finalised at the time of writing. First results appear very impressive (see below).

Example images: We illustrate the capabilities of the instrument by showing a series of interesting examples. In Figure 1, an extract from one of our browse products is shown. The north facing wall of this crater in Nepenthes Mensae shows a large number of gullies. At the highest resolution, boulders can be seen at the foot of the slope. This image was taken in the NIR channel (930 nm) of CaSSIS.

In Figure 2, an anaglyph has been produced from a stereo pair. The target was a set of gullies east of Argyre basin near the Karpinsk impact crater. Using 3D-glasses the ridge becomes clearly evident and gullies on both sides can be seen. East is roughly downwards in this representation (which is required to produce the optimum visual effect).

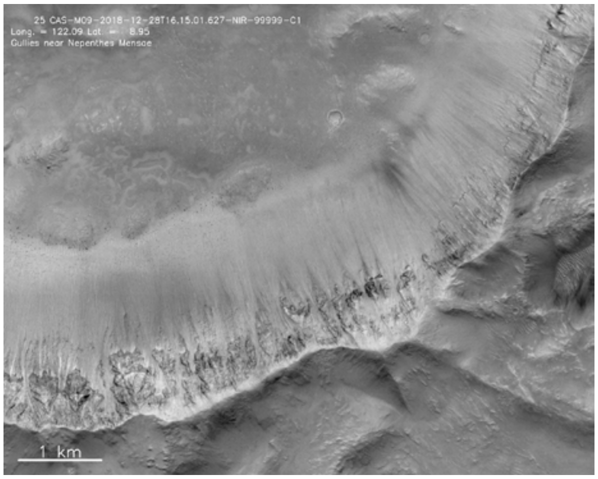

Figure 1 Gullies near Nepenthes Mensae. A single-colour non-geometrically-corrected browse product showing gullies on the north-facing slope of a crater with boulders at the base.

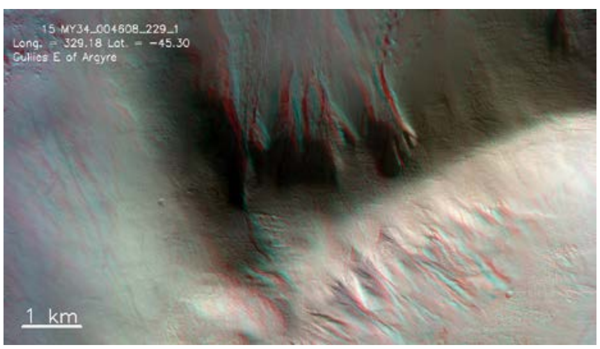

Figure 2 Anaglyph (red-blue) of gullies east of Argyre basin near Karpinsk crater.

Figure 3 shows an example of a colour product composed from the NIR, PAN and BLU filters.

Future observations: CaSSIS and TGO are funded through to the end of 2020 with a probable extension. Observations near previous landing sites (e.g. Gale crater) and future landing sites (e.g. Jezero) have also been acquired and, with the spacecraft roll capability now functional, can be acquired with reasonable frequency.

Conclusion: CaSSIS provides a new highly-valuable data set for the study of the Martian surface at optical wavelengths, and variable times of the day. We have developed most of the tools necessary to provide automatically-generated colour and stereo products. The products from the first months of the primary mission will be made available to the community through the Planetary Science Archive and through our own web site this year. Several other presentations at this conference will discuss specific science results incorporating CaSSIS data including observations of the ExoMars 2020 rover landing site in Oxia Planum.

Acknowledgements: The authors thank the spacecraft and instrument engineering teams for the successful completion and operation of CaSSIS. CaSSIS is a project of the University of Bern funded through the Swiss Space Office via ESA's PRODEX programme. The instrument hardware development was also supported by the Italian Space Agency (ASI) (ASI-INAF agreement no.I/018/12/0), INAF/Astronomical Observatory of Padova, and the Space Research Center (CBK) in Warsaw. Support from SGF (Budapest), the University of Arizona (Lunar and Planetary Lab.) and NASA are also gratefully acknowledged.

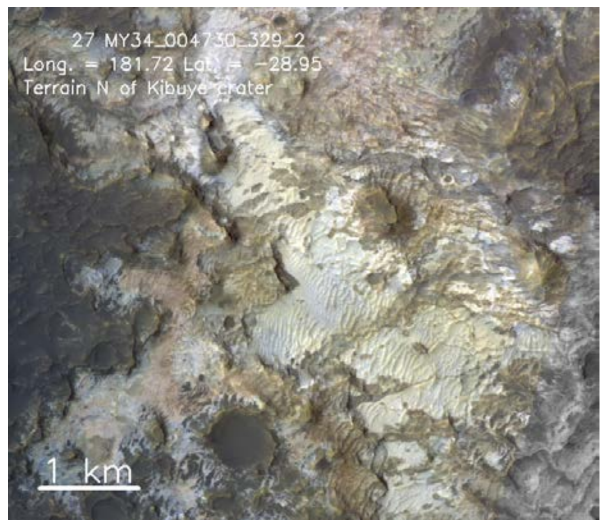

Figure 3 Colour variations evident north of Kibuye crater in Terra Cimmeria.

References:

[1] Thomas, N. et al. (2017) Space Sci. Rev., 212, 1897. [2] Roloff, V. et al. (2017) Space Sci. Rev., 212, 1871. [3] Tornabene, L.L. et al. (2018) Space Sci. Rev., 214, 18. [4] Vago, J., et al. (2015), ESA ExoMars program: The next step in exploring Mars, Solar System Research, 49, 518-528. [5] Thomas, N. et al. (2019) LPSC this conf.