The colours of Mars: Exploring the red planet with CaSSIS

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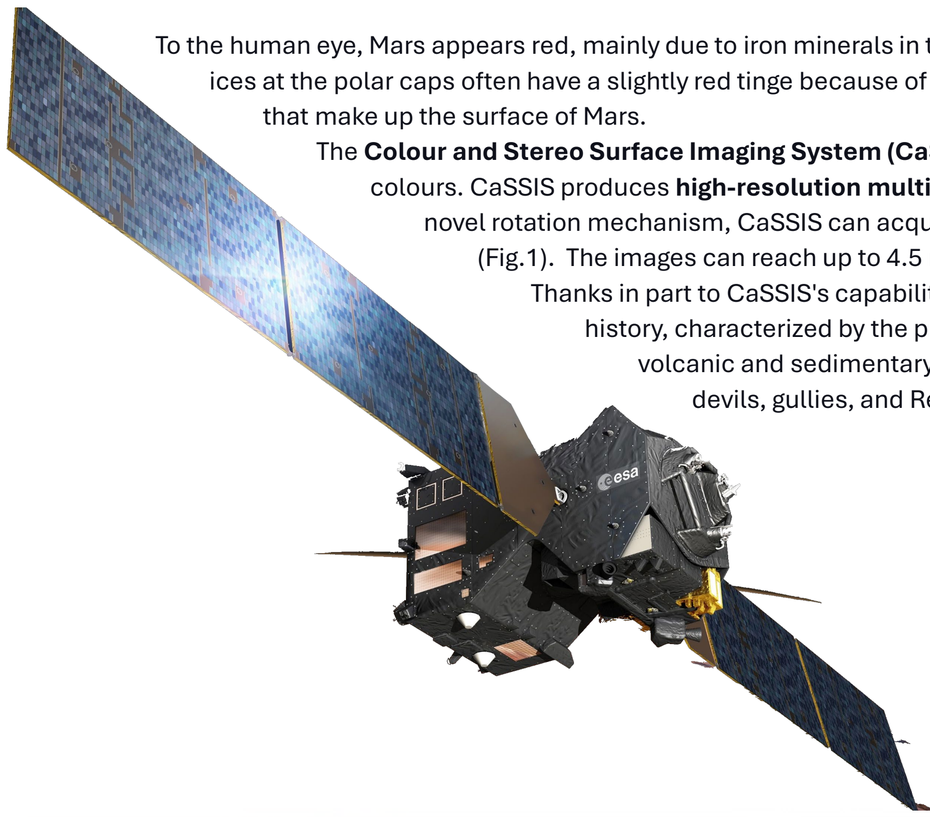


To the human eye, Mars appears red, mainly due to iron minerals in the Martian regolith that are oxidized, or “rusted”, giving the surface its characteristic reddish-brown tint. Even its white seasonal ices at the polar caps often have a slightly red tinge because of the scattered Martian dust that gets deposited. Such a hue, however, hides the incredible variety of minerals and lithologies that make up the surface of Mars.

The **Colour and Stereo Surface Imaging System (CaSSIS)** onboard the ESA ExoMars Trace Gas Orbiter allows us to probe for such differences, revealing a striking diversity of colours. CaSSIS produces **high-resolution multispectral stereo images of Mars in four bands** spanning the blue, visible, and near-infrared wavelength ranges. Thanks to its novel rotation mechanism, CaSSIS can acquire image pairs that are stereo-compatible, which can be used for three-dimensional surface reconstruction photogrammetry (Fig.1). The images can reach up to 4.5 m/px in spatial resolution from the TGO 400 km circular orbit and acquire at various times of the day and seasons of the year.

Thanks in part to CaSSIS's capabilities, in orbit from April 2018, the evolving research shows how Mars has been affected by a very diverse and complex geological history, characterized by the presence of wet and dry periods with bodies of water stable for very long periods, perhaps even oceans. In addition to past volcanic and sedimentary processes, Mars still exhibits active dynamical processes such as, for example, dune migration, dry dust avalanches, dust devils, gullies, and Recurring Slope Lineae (RSL), as well as seasonal sublimation of polar caps and frost deposition.

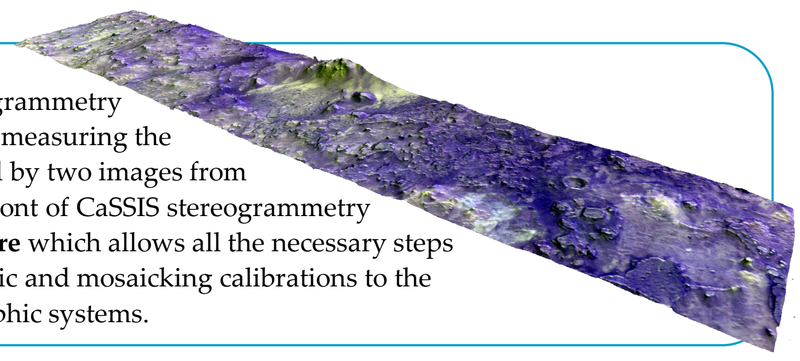
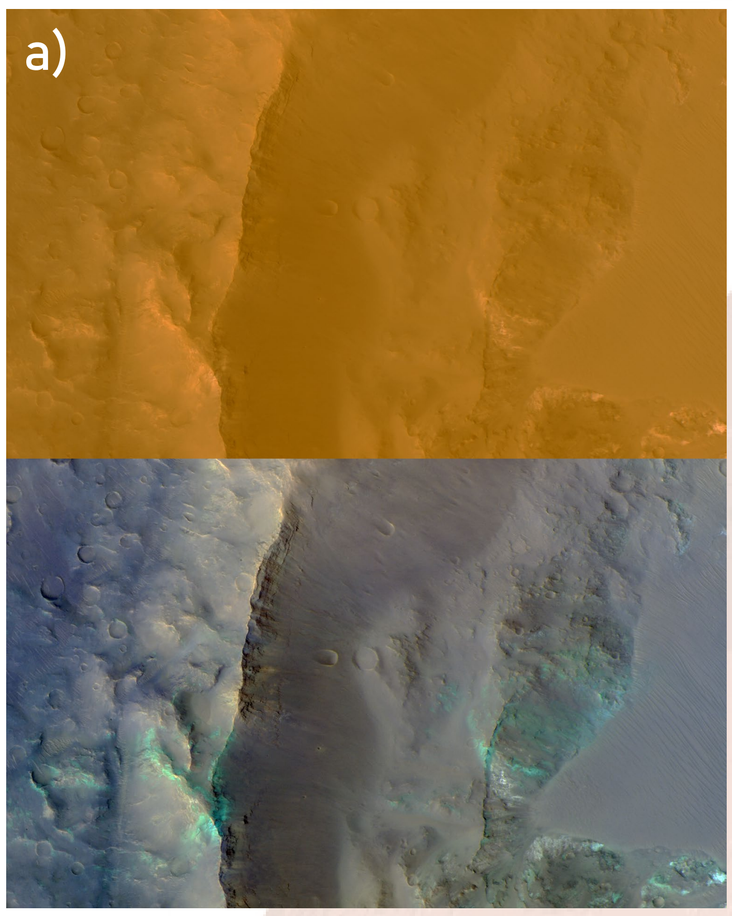
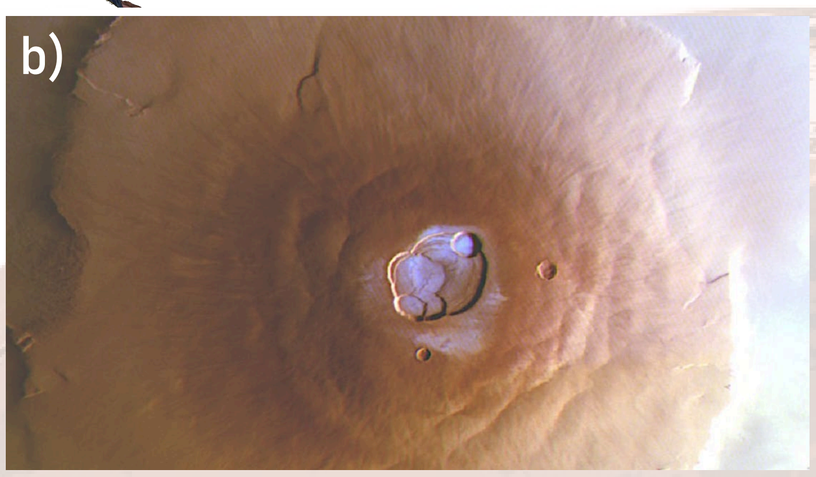


Fig.1 CaSSIS stereo processing:
Stereophotogrammetry is a branch of photogrammetry based on **stereoscopic** principles. It involves measuring the 3D coordinates of points of objects portrayed by two images from different points of view. INAF is at the forefront of CaSSIS stereogrammetry due to the development of the **3DPD software** which allows all the necessary steps to reconstruct the topography, from geometric and mosaicking calibrations to the triangulation and projection in Mars geographic systems.

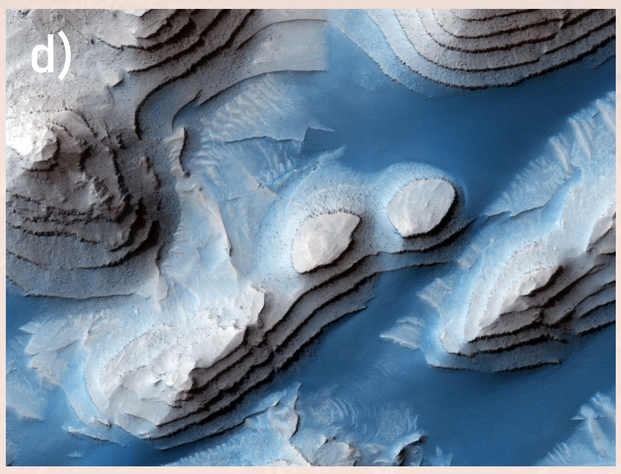


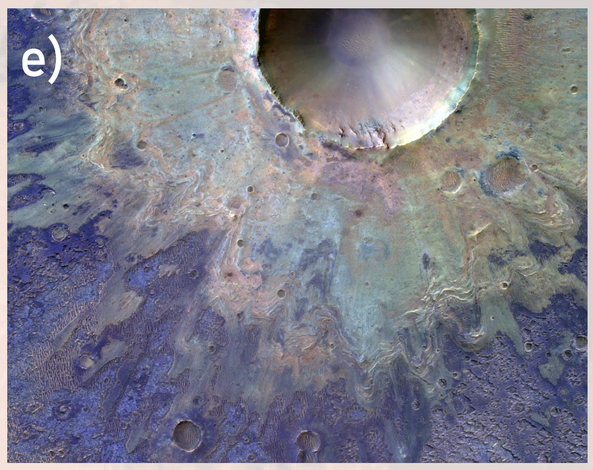
a) The comparison of RGB colours similar to what perceived by the human eye (top) with respect to what CaSSIS can highlight (bottom). This Alga Crater portion shows greenish colours typical of mafic minerals such as magnesium and iron-rich silicates, and the bluer tones of the dust.

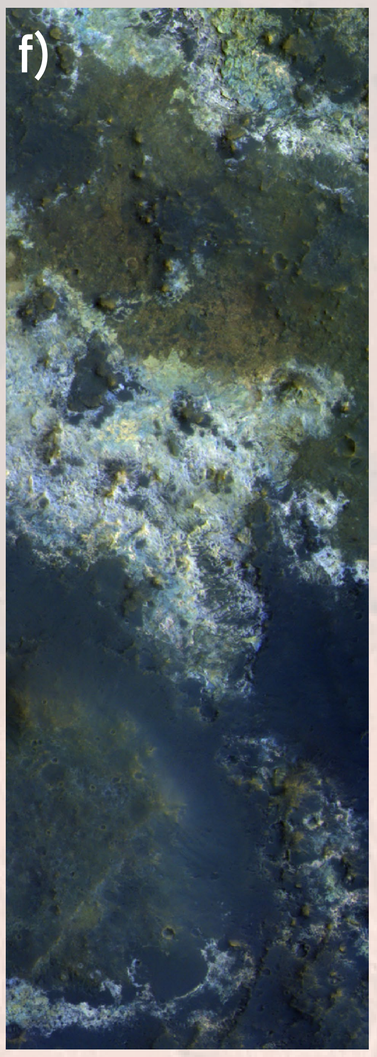


b) Transient morning frost deposits in the calderas of the Olympus Mons volcano in the Tharsis region. This recent discovery suggests an active exchange of water between regolith and atmosphere with implications on the Mars water cycle.

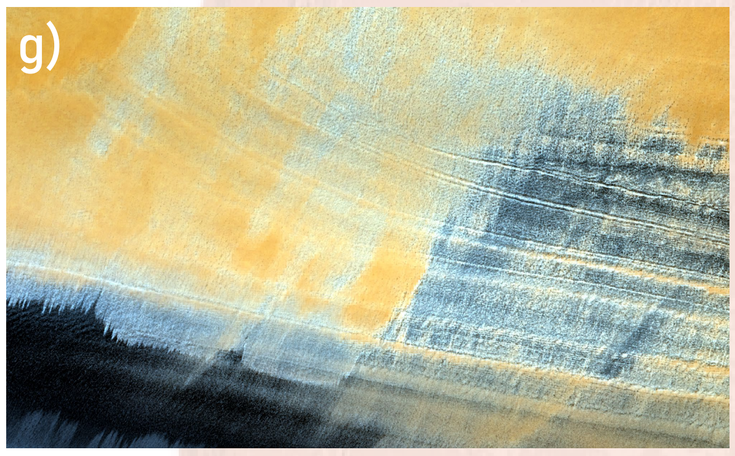
f) The unusual morphology of the ejecta of this 8 km diameter crater in Utopia Planitia suggests the presence of ice melted by the impact.





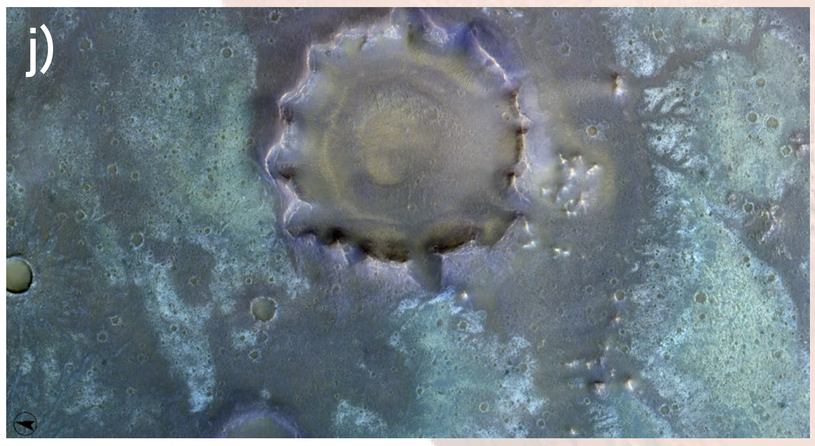


A mosaic of images showing **d)** exposed layers in Danielson Crater, **e)** part of a crater in Ganges Chasma and its colourful ejecta and **f)** the floor of the Mawrth Vallis. The different hues unveil a variety of sulphates and clays sedimentary rocks, deposited in a succession of different environmental conditions.



g) Exposed layers of the north polar cap on which dust is deposited due to atmospheric transport. The image is derived from the fusion of a MRO CRISM hyperspectral image with CaSSIS via pansharpening, greatly improving the original spatial resolution.

The sky of Mars from surface as observed by the MSL Curiosity rover: **h)** a feather-shaped iridescent cloud, or "night-shining" clouds. This phenomena is supposedly the result of the interaction of sunlight with water vapour and ice crystals. **i)** The blue sunset of Mars.



j) The incised Morella Crater in Vallis Marineris region, **f)** the fluvial delta in Jezero Crater and **l)** karst-like features in Meridiani Planum are remnants of past erosion and deposition events from Mars' "Wet period".