POLAR SPOTS ON MARS OBSERVED WITH THE COLOUR AND STEREO SURFACE IMAGING SYSTEM (CaSSIS).

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Introduction: Many observations of the polar and circum-polar Martian surface have led to a better understanding of the processes occurring there at different seasons of the Martian year. A conceptual model was proposed by [1] for the formation of polar spots, dark fans and araneiform terrain in the southern hemisphere, which is in agreement with observations thus far [2]. Those features appear in certain regions where approximatively 1 m of CO_2 ice deposited during winter and becomes an impermeable translucent slab after cleaning processes in early Spring [1]. Insolation heats the substrate, leading to CO_2 ice sublimation at the slab's base which results in a pressure rise. The slab weakens and then ruptures locally to release the pressure, forming jets of CO_2 gas carrying sand and dust, which result in fans and dark spots. The gas flow below the ice erodes the substrate to form araneiform beneath a spot (fig.4 in [1]).

The Colour and Stereo Surface Imaging System (CaSSIS) [3] is the high-resolution imager onboard ESA's ExoMars Trace Gas Orbiter (TGO), built at the University of Bern. The goals of CaSSIS are to analyse and image surface features, map regions of trace gas origination, search for possible new landing sites candidates and certify their safety. Its high sensitivity and the non-Sun synchronous orbit of TGO allow CaSSIS to acquire high quality images of the surface at various local times during the entire year. Although TGO's orbit inclination of 74° prevents the observation of the poles, circumpolar processes occurring in a 70-74° latitude band can be studied in great detail.

Observations: CaSSIS is able to observe the surface in up to four colours at variable times of the day and year, which allows the Science Team to complement the analysis of seasonal processes with new and unique data. Figure 1 shows the evolution during southern spring of dark spots located across a layered plateau at 72°S latitude. The first two images are taken around the end of Southern Winter, the third in the end of Spring and the final image is taken at the beginning of Summer. The albedo and colour of features in this scene show a spectacular seasonal evolution. Dark spots appear first on layers all around the plateau at the end of winter and then cover the entire plateau, giving it a distinctive blue colour. By the end of spring, most of the plateau has been cleaned from spots and shows bright ice. By summer, some of the spots are still discernible at the surface but dust devil activity rapidly redistributes dust.

Generally, such dark deposits remain cold throughout the beginning of springtime which suggests that they are thin enough to stay in thermal contact with CO_2 ice [4]. They are, in some cases, paired with brighter bluish haloes, possibly results from re-condensation of CO_2 from the jet [5,6]. Alternatively, the dark dust grains might sink into the CO_2 ice layer and provoke this blue colour when seen through the CO_2 ice, as indicated by CRISM spectra that show similar spectral slopes for dark material and blue haloes [7].

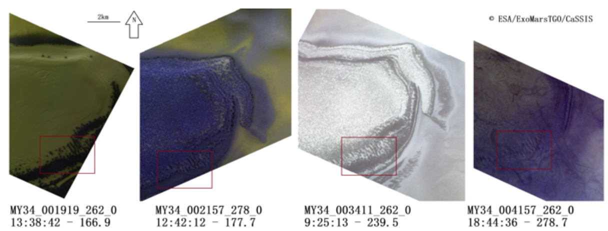

Figure 1: Time evolution of blue spots on a layered plateau in an unnamed crater located between Hutton and Burroughs craters (72°S , 110°E). The red square identifies same features through time.

Beside the "classical" dark spots seen in Fig. 1, another type of spots and fans, of similar shape and size but with a clear difference of colour, is observed in a single CaSSIS image (Fig. 2) taken near Sisyphy Montes at the end of the Southern winter. The reasons for the observed differences are still under investigation. Based on their morphologic similarities with the other well-known sublimation-driven features, they seem to also originate from jet-like processes. A topography-related deposition could also be considered based on the observed density, though spots and fans are present on the smoother areas in smaller concentrations. Several questions are raised by this observation:

- Is this behaviour recurrent in this area?
- If yes, is there a common origin between the dark spots covered in the literature and these features?
- Can a temporal evolution be established and a formation mechanism be theorised based on observations?
- If an evolution is established, what is the interpretation of the observed colours and the relation to composition?

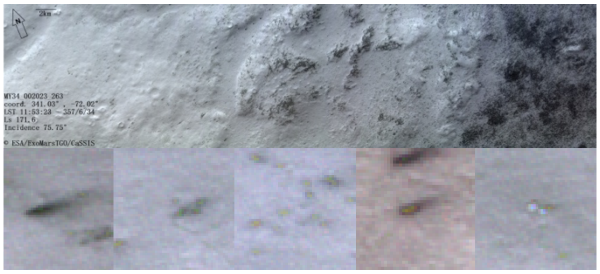

Figure 2: (Top) CaSSIS image taken on May 7th 2018 near Sisyphy Montes (72°S , 341°E) at a solar longitude of 171.6° - end of the Southern Winter. It shows dark material unequally parsed along the image, a few darker "fans" and bright spots. (Bottom) Zoom on different coloured fans, mean size of 100m.

Results and discussion: Eight reflectance profiles were taken across all four CaSSIS images presented in Fig. 1. The example of a particular profile (#8) and its variation through the images is shown in Fig. 3. The effects of the darker spots on the reflectance profiles are generally obvious (long-period wells on red and blue curves in both filters, on black and green curves only in NIR filter).

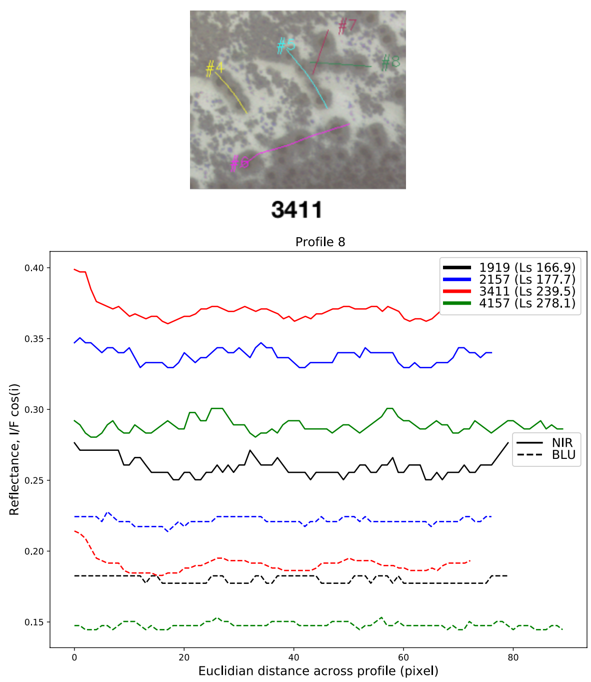

Figure 3: (Top) Profiles in CaSSIS images located at 72°S and 110°E. (Bottom) Reflectance values for profile #8 for four different images at variable L_s, for the NIR and the BLU filters.

A clear increase of reflectance is seen from winter to spring, then in summer the reflectance decreases as the ice sublimates. The most impressive change is between the black and blue profiles which are taken only 11° of L_s apart (167° and 178° respectively) and show an increase of reflectance of 20%.

The study of reflectance in the orange/yellow features shown in Fig. 2 indicates that the PAN reflectance values decrease in the spot while the RED-NIR reflectance values increase or remain stable. Green features display a similar decrease of reflectance in PAN and NIR but an increase in RED. One question that comes to mind is whether these fans and spots originate from the same process as the “classical” dark spots with blue haloes. A possible evolution can be theorised from the CaSSIS observation, in which the first step is the deposition of black fans on top of the ice. These fans then experience a change of colour at their centre, the dark contour disappearing gradually so that only a coloured spot remains visible for some time before fading away entirely. This behaviour has not yet been explained experimentally nor theoretically and is still under investigation.

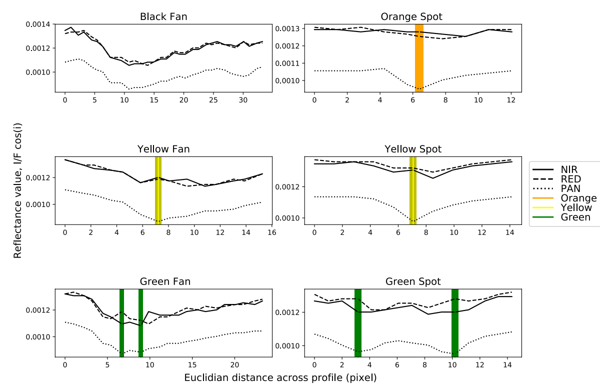

Figure 4: Profiles of reflectance values across some spots and fans observed in Fig. 2.

Future observations: So far only one CaSSIS image has shown the behaviours shown in Figs. 2 and 4 and new observations of the same area will help understand the reason for these peculiar spectro-photometric behaviours. Comparison with other instruments (CRISM, HiRISE) might also provide valuable insights. Experimental work is planned to better understand the relationship between colour and composition.

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