Exploring Mars through geologic time: from past to present & towards the future

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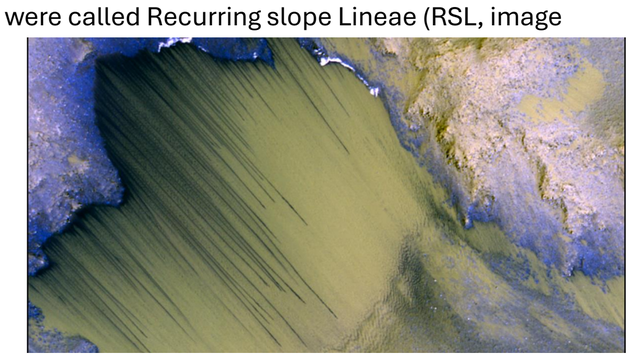
Introduction

The surface of Mars records traces of events dating back to immediately after planetary formation, followed by periods of Earth-like habitable environments that then transitioned to the present-day dry, cold and inhospitable conditions. This makes the Red Planet the only other planetary body in the Solar system beyond Earth with an easily accessible geologic history that was similar to the Earth. Studying its surface is therefore crucial for understanding its past habitability and climatic conditions and how they evolved with time. It is also pivotal for assessing its In Situ Resource Utilization potentials, a crucial aspect for the future human and robotic exploration missions. The planetary science research group at OAPD is actively involved in many research projects on the multidisciplinary analysis of Martian surface landforms, locations and features that record past and/or present-day aqueous or glacial processes. We present a set of published and ongoing studies aimed at investigating a) candidate past & present-day Martian surface features related to the flow of liquid water b) periglacial landforms, c) characterization of Martian locations suitable for a possible human and/or robotic exploration mission.

The Origin and Formation mechanism of RSL: is there flowing liquid water on Mars *as we speak*?

Back in 2011, McEwen e al., (2011) discovered dark, linear to sinuous, flow-like features resembling water flows that we observe in Antarctica. These were called Recurring slope Lineae (RSL, image below) and they are characterized by:

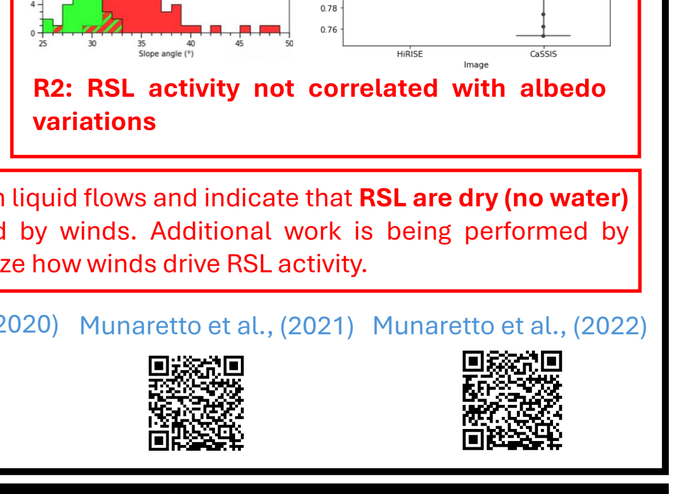


- Flow activity during warm seasons
- Occurrence in steep sloped areas
- Flow disappearance during cold seasons
- Yearly recurrence in the same locations

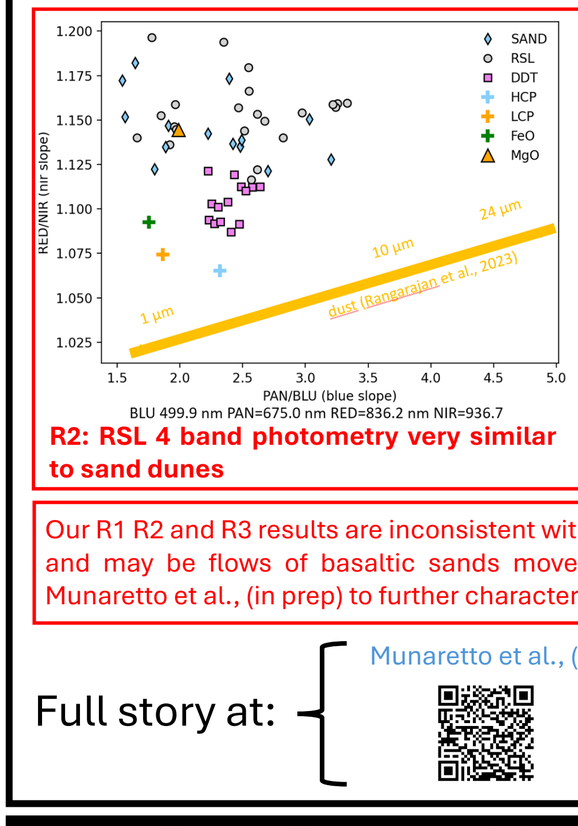
They were initially attributed to **liquid water**, possibly mixed with salts (i.e, brines). It is however very unlikely for water to be flowing on Mars, although theoretically possible transiently at very specific temperature and pressure conditions. Further studies also proposed dry alternatives like **debris flows, wind streaks, grainflows.** This dilemma has been open for more than 10 years, and it is now in the process of being solved. Many recent studies pointed out that RSL are probably dry, although the exact formation mechanism is still not understood.

We performed a series of multidisciplinary analyses:

- geologic context (steepness and orientation) of RSLs
- photometry (diurnal albedo variation due to different amount of volatiles in the regolith)
- thermodynamic environment (thermal modelling to assess if brine melting is physically possible)
- 4 band RSL spectra & comparison with features of known origin (sand dunes, dust devils)
- Spatial distribution of RSL on Mars



R1 : RSL activity not driven by temperature but by gravity!



R2: RSL 4 band photometry very similar to sand dunes

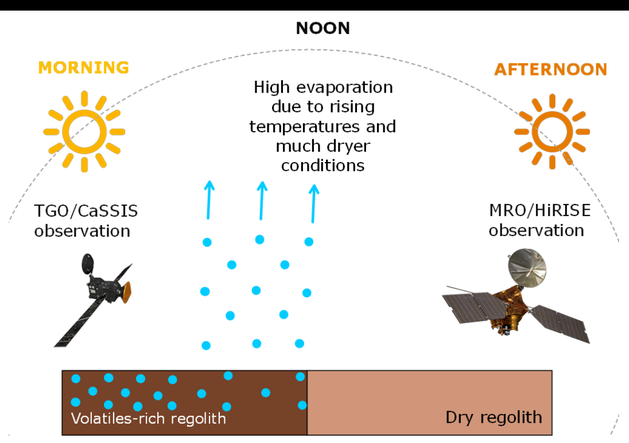
R2: RSL activity not correlated with albedo variations

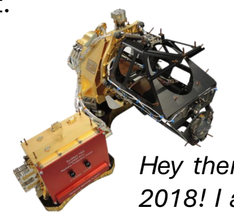
Our R1 R2 and R3 results are inconsistent with liquid flows and indicate that **RSL are dry (no water)** and may be flows of basaltic sands moved by winds. Additional work is being performed by Munaretto et al., (in prep) to further characterize how winds drive RSL activity.

Full story at: Munaretto et al., (2020) Munaretto et al., (2021) Munaretto et al., (2022)

HiRISE & CaSSIS Coordinated Imaging Campaign (*Work in progress*)

We are performing a novel, first of its kind observational campaign to observe a set of locations during the early morning with CaSSIS and on the afternoon of the same day with HiRISE. Such dataset will allow to characterize volatile-exchange mechanisms between the regolith and the atmosphere and see if they can explain many active Martian surface features, such as RSL, gullies, araneiforms, polar spots and many others. This activity is being performed in collaboration with the University of the Arizona, responsible for the HiRISE instrument.



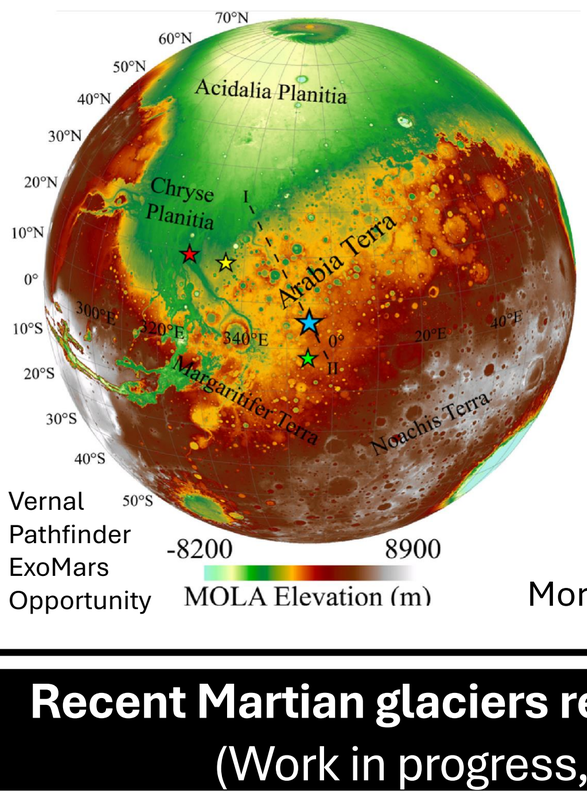


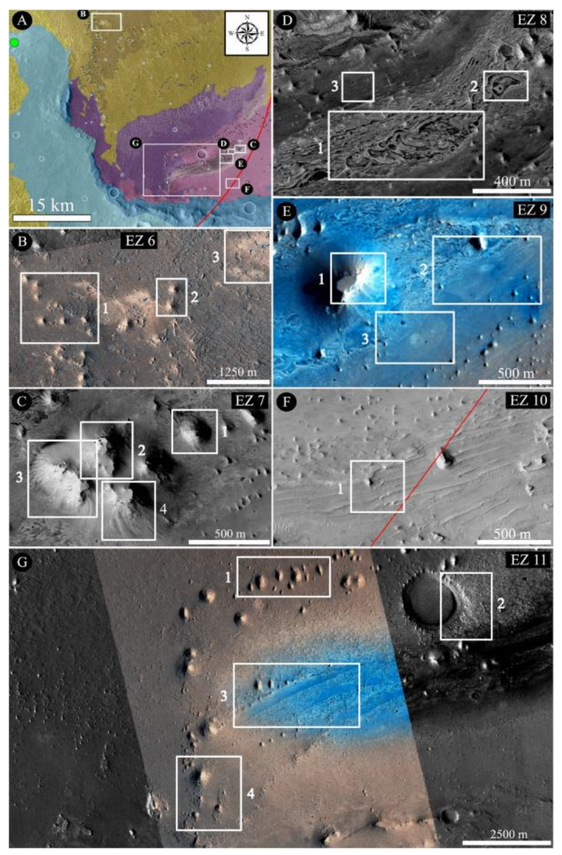
Hey there! I am CaSSIS, a stereocamera orbiting Mars since October 2018! I am taking pictures at 4.6 m/px in four bands, even in stereo to produce Digital Terrain Models of the surface!

Where Shall We Land on Mars?

We identified and characterized the scientific potential for a future possible human landing site on Mars, located at Vernal crater. It features:

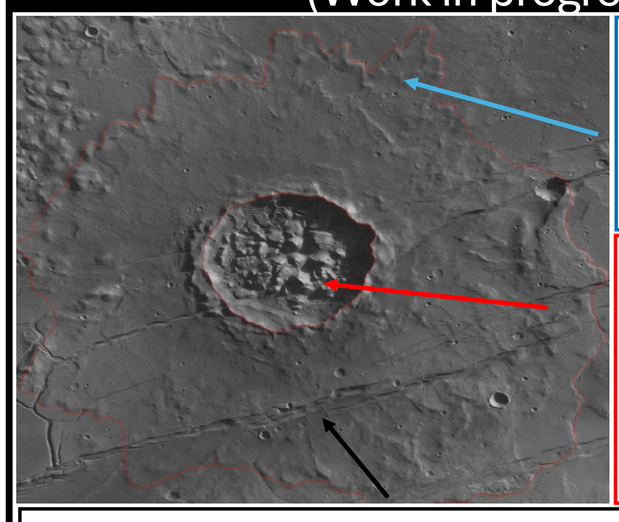
- Flat areas for safe landing and operations of a human mission to Mars.
- High amounts of sub-surface ice, pivotal for ISRU.
- Putative ancient hot springs environments that have a very important astrobiological potential
- Past Aeolian features, allowing to characterize the present and past Martian climate





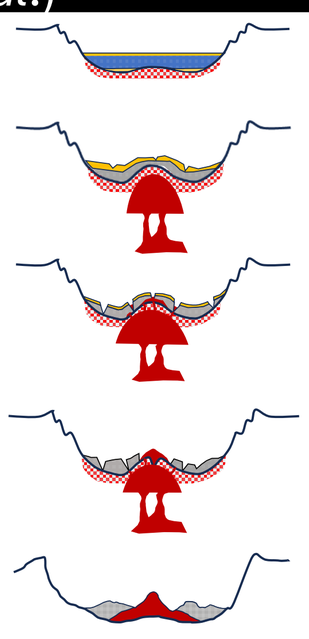
More about it in Pajola et al., (2022)

Floor Fractured Craters : A Song of Ice & Fire (Work in progress, *Bertoli et al.*)



ICE : fluidized morphology of the ejecta indicate ice-rich terrain during the impact

VOLCANISM suggested by tilting of the mesas and presence of olivine and pyroxenes in the crater



TECTONICS : same fracture geometries in the floor as in the Sirenum Fossae grabens, favouring volcanic injection and the ice melting in the crater floor

Recent Martian glaciers retreat revealed by *Eskers* (Work in progress, *Munaretto et al.*)

Eskers are sinuous ridges sediments deposited by meltwater from a retreating glacier or ice sheet. We identified several new Martian Eskers and are investigating their topography, geologic context and to study the Red Planet's paleoclimate and its ancient glaciers retreated.