National Aeronautics and Space Administration

Spiders on Mars, Europa, and in the Laboratory

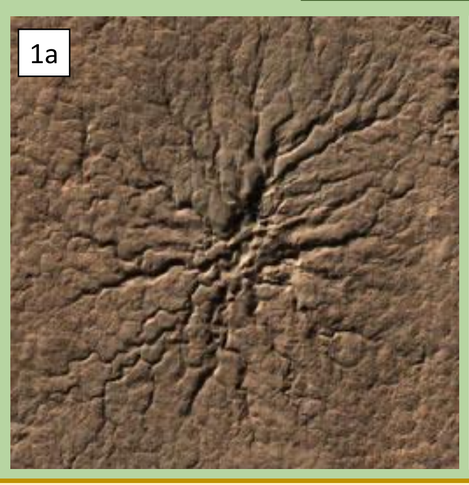
Lauren Mc Keown[1], JPL Postdoctoral Fellow (3223), Serina Diniega[1] (3223), E. Lesage[1], J. E. C. Scully[1], E. J. Leonard[1], R. T. Pappalardo[1], M. Potter[1], V. C. Tsai[2], M. Choukroun[1], M.J. Poston[3], E. Carey[4], C.J. Hansen[5], G. Portyankina[6], K.-M Aye[7], S. Piqueux[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [2]Brown University, Providence, RI, USA, [3]Southwest Research Institute San Antonio, TX, USA, [4]Airborne Snow Observatory, Crowley Lake, CA, USA, [5]Planetary Science Institute, Tucson, AZ, USA, [6]German Aerospace Center (DLR Berlin) Rutherfordstraße 2, Berlin, Germany [7]Freie Universität Berlin, Kaiserswerther Str, Berlin, Germany

Introduction

Dendritic, fractal patterns form on Earth within systems of growth, typically driven by a **physical gradient,** e.g. river drainage networks. Recently, similar patterns have been detected on planetary surfaces. South polar **`Spiders' on Mars** are thought to form via a **solid-state-greenhouse effect**, where trapped gas beneath seasonal $CO_2$ ice rushes towards a vent, scouring the substrate, while the origin of a peculiar asterisk-shaped `spider' in Europa's Manannán crater is uncertain. We present experiments to test the formation of Martian spiders. We investigate controls on their different morphologies and whether they are active features, or relicts from a past climate. We present a new hypothesis for the formation of Europa's Manannán spider, with `lake stars' as a terrestrial analog, and experiments to test this. These small—scale experiments exemplify how, despite the issue of equifinality, we can understand extant surface processes through comparative planetology – on the large and small scale.

Spiders on Mars

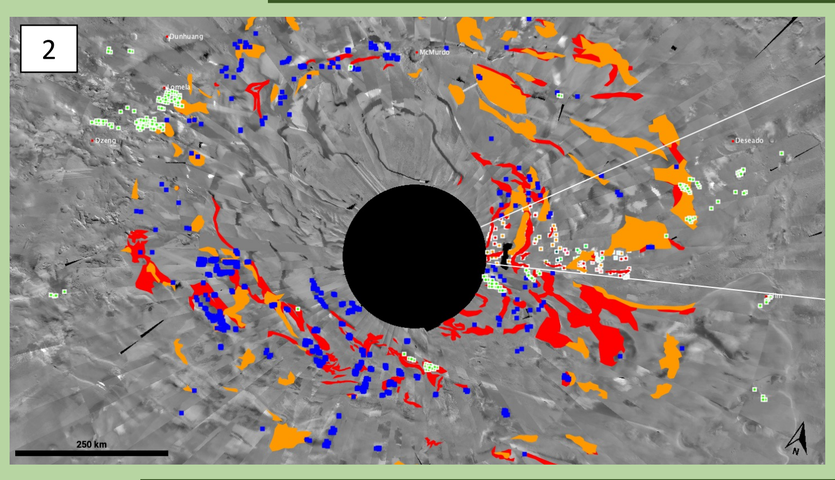


Spiders (1a) are dendritic, negative topography features in the Martian south polar region [1]. They are often radial, range in scale from <50 m to 1 km and have morphologies ranging from `fat' to `thin' to `starburst'. In southern spring, dark albedo fans and spots emanate from within their troughs that form the `Kieffer Model' (1b): sunlight penetrates translucent CO_2 slab ice and thermal wavelengths get trapped, heating the regolith. Eventually the ice cracks and gas rushes towards this `vent', entraining loose material that is deposited on top of the ice in the form of a fan or spot, and carving the `spider' in the substrate.

Are spiders forming/growing the present, or are they relicts from a past and different climate?

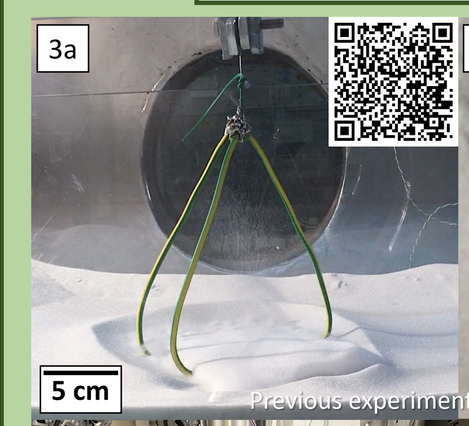
- Despite ongoing fan and spot activity, and several Mars years of careful observations, spiders have not been observed by the High Resolution Imaging Science Experiment (HiRISE) to grow or newly form today.
- Newly-forming smaller dendritic troughs and sand furrows have been found within dune fields.
- What environmental factors govern the range of spider morphologies?

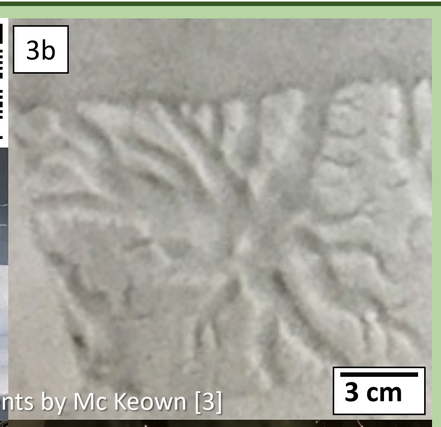
Measuring Martian Spiders



We are surveying spiders in CTX images, to identify correlations between spider morphology and local geology and ice properties. We then test these in the lab. We have mapped spiders around the Martian south pole (to -80°N), and now are focused on a latitudinal transect.

Martian Spider Analog Experiments in EMSiL





Previous experiments by Mc Keown [3]

Current experiments by Mc Keown in EMSiL

We aim to simulate the Kieffer model in JPL's Extraterrestrial Materials Simulation Laboratory (EMSiL).

Our previous experiments [3] were the first to form spider morphologies by sublimating CO_2 ice over granular material at room temperature. Our next step is insolating a conformal layer of translucent CO_2 ice on Martian simulant with a solar simulator, under Mars winter conditions.

So far, we have produced the thickest reported translucent CO_2 ice layer.

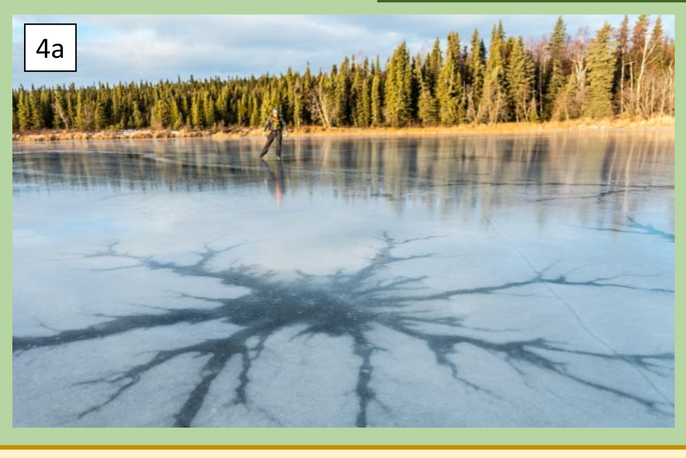
In the laboratory, we will vary these factors and compare with resultant spider morphometrics:

- **Ice thickness**
- **Ice composition/structure (cracked, filled with dust etc.)**
- **Water frozen into sediment**

This work can help us understand how CO_2 ice modifies the surface of Mars, in the past and present.

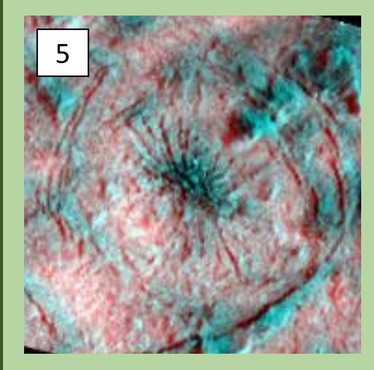
References: [1] Piqueux et al., (2003) JGR: Planets. [2] Kieffer et al., (2006) Nature. [3] Mc Keown et al., (2021) Scientific Reports. [4] Steinbrügge et al. (2020) Geophysical Research Letters [5] Tsai & Wettlaufer, (2007) Physical Review E. [6] Bowling et al., (2019) Icarus. [7] Lesage et al., (2022) The Planetary Science Journal. [8] Hand & Carlson, (2015) Geophysical Research Letters

Lake Stars on Earth



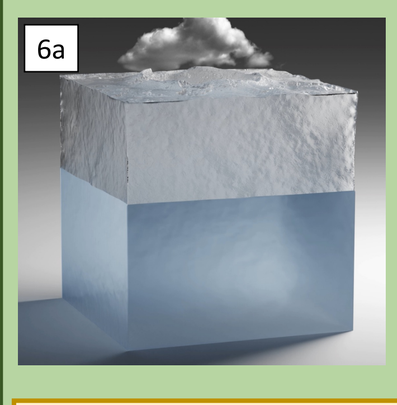
Lake stars (4a,b) are striking patterns that develop on the surface of ice-covered lakes on Earth in winter. When a lake surface freezes and snowfall covers the thin ice, the snow develops into slush. The ice cracks and relatively warm water wells through the snow or slush, melting it [5]. Locations with faster flow rates melt preferentially, leading to an instability that results in `fingers' [5, 6]. Eventually the water freezes, preserving this `star-like' pattern encased within the ice.

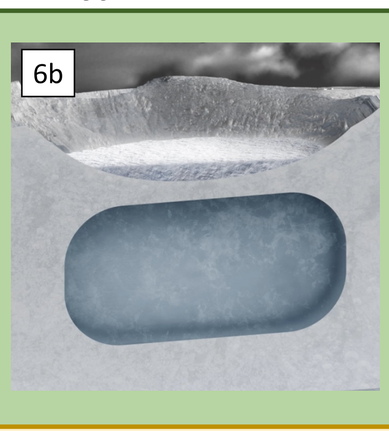
Spider on Europa



The asterisk-shaped `spider' at the center of Manannán crater has been proposed to consist of fractures originating from a brine source within Europa's icy crust [4]. However, due to limited spatial resolution of the Galileo Solid State Imager in this area (20-100 m/pixel), negative topography of the linear features cannot be confirmed. Additionally, [4] invoke the Kieffer model, citing radial fractures as evidence for a rigid surface subject to pressure from below. However, Martian spiders are not ice fractures; they are negative topography troughs eroded into loose regolith.

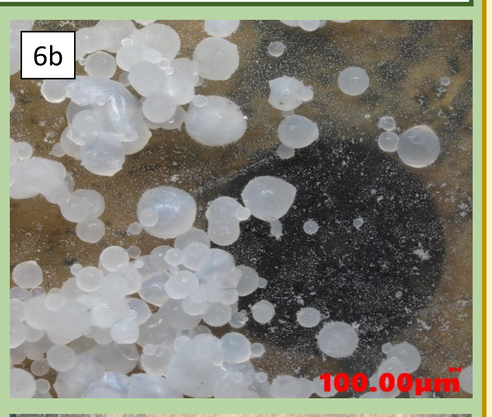
New Lake Star Formation Hypothesis for Europa's Manannán Spider

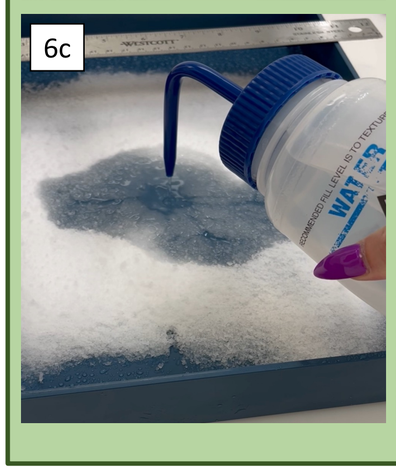


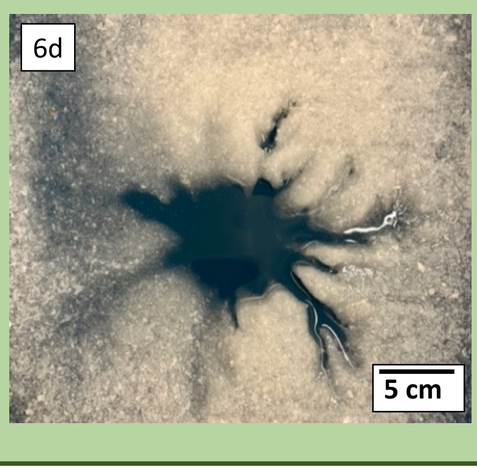


1. Following impact, a transient atmosphere and a brine pool formed (6a).
2. During cooling, impact slurry covered an ice layer above the brine pool (6b).
3. The ice cracked, and liquid brine spread through the slurry (6c). As temperatures and pressures were elevated [6], brine could remain as liquid transiently. Partial vaporization upon the brine surfacing also increased local pressure [7]. Similarly to lake stars (though under different pressure and temperature regimes), water spread and melted the slurry to form a `spider' pattern, which was preserved as it froze. The spider has a low relative albedo because of its higher salt concentration, which darkened over time due to radiation exposure [8].

Europa Lake Star Experiments in LN_2 Glovebox







Using a LN_2-cooled glovebox under post-impact surface temperature regimes (~0 °C) we flow liquid water onto Europa granular ice simulant (average diameter 317 µm), with and without $MgSO_4$). In all cases:

- 'Lake stars' develop, with patterns growing from the center
- Patterns were more distinct for higher ΔT between water and simulant and lower concentration of salt.

The next step is to perform experiments under post-impact pressure ranges. This work can help us understand cryovolcanic processes and the transient conditions after impact on Europa.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
www.nasa.gov

Poster Number: **PRD-P#005**

Publications:

- **L. Mc Keown**, M. Bourke, J. McElwaine, M. Sylvest, and M. Patel. The Formation of Araneiforms by Carbon Dioxide Venting and Vigorous Sublimation Dynamics Under Martian Conditions. **Nature Scientific Reports**, 2021.
- **L. E. Mc Keown**, M. C. Bourke, and J. N. McElwaine. Experiments on Sublimating Carbon Dioxide Ice and Implications for Contemporary Surface Processes on Mars. **Nature Scientific Reports**, 2017.
- **L. E. Mc Keown**, E. Lesage, J.E.C. Scully, E.J. Leonard, R.T. Pappalardo, M. Potter, V.C. Tsai, M. Choukroun, S. Diniega. Lake Stars as an Analog for Europa's Manannán Crater Spider Feature, (in prep)

Author contact information: lauren.mckeown@jpl.nasa.gov