



La lumière pour étudier les surfaces planétaires

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Lundi 24 Juin 2019



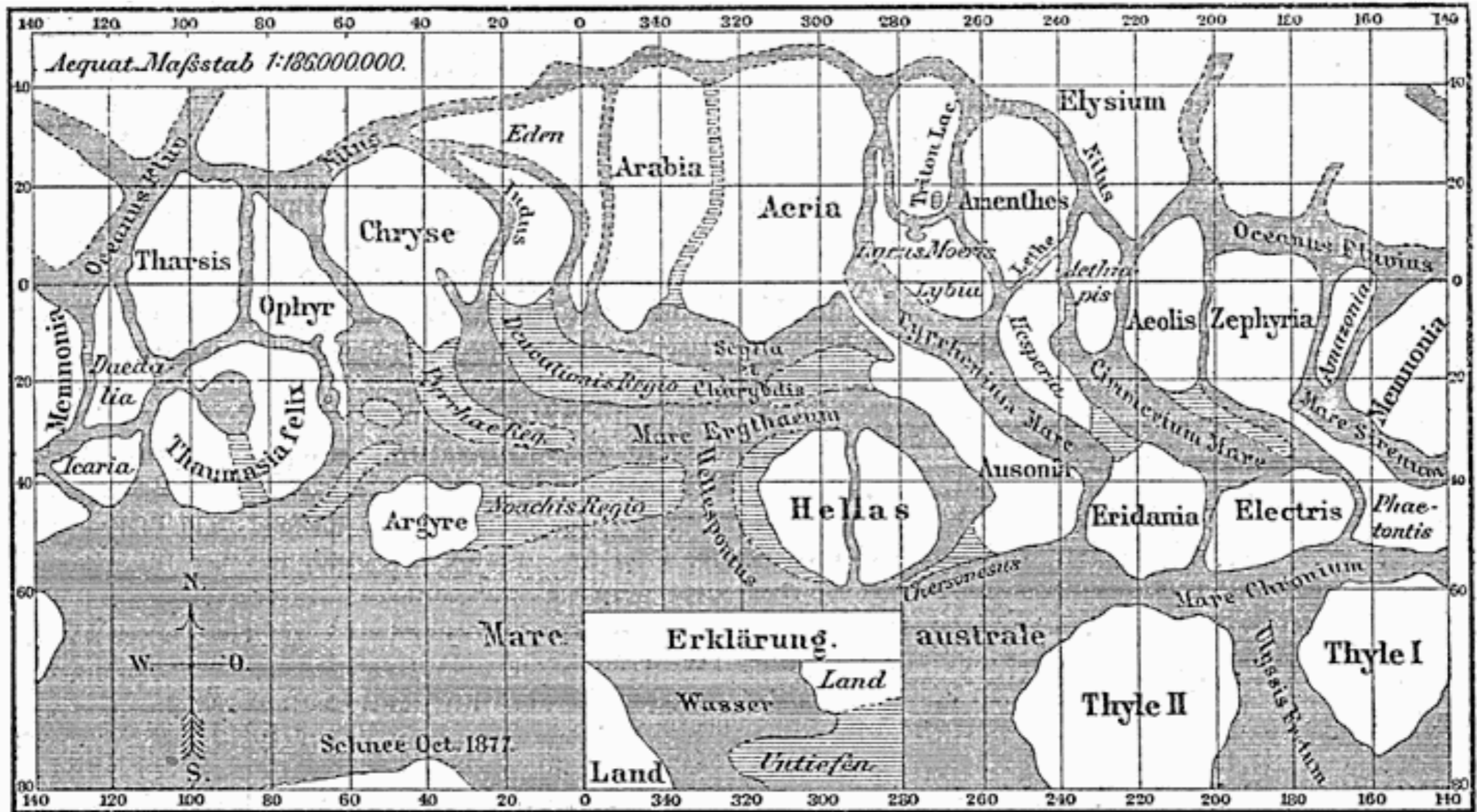
Images of Mars

Mars

- Red point in the sky
- Greek god of War

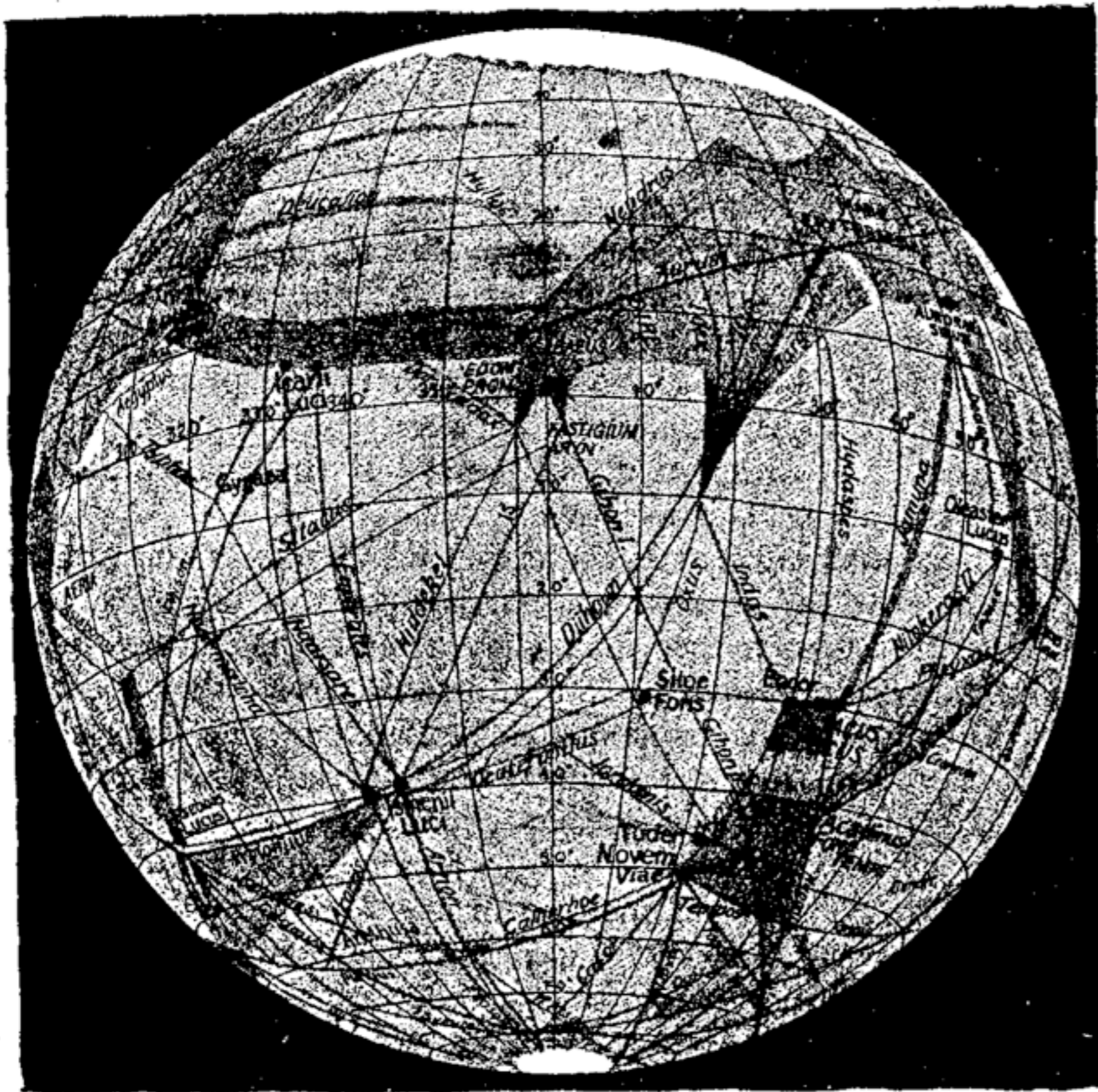


Schiaparelli's map (1877)



- Drawing using persistence of vision

Lowell's map

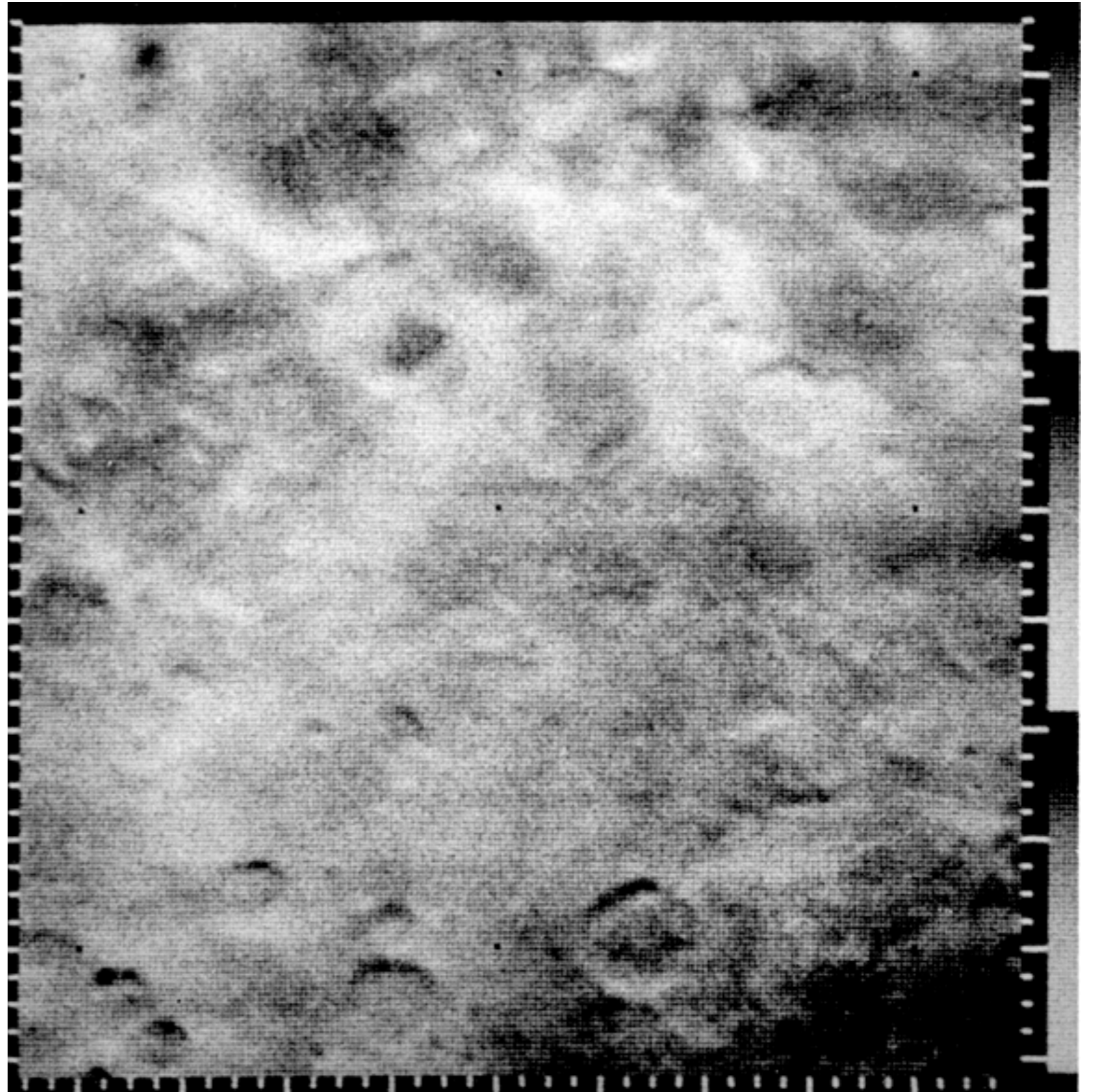


- Annotated photograph (1905)
- Martian civilization interpretation

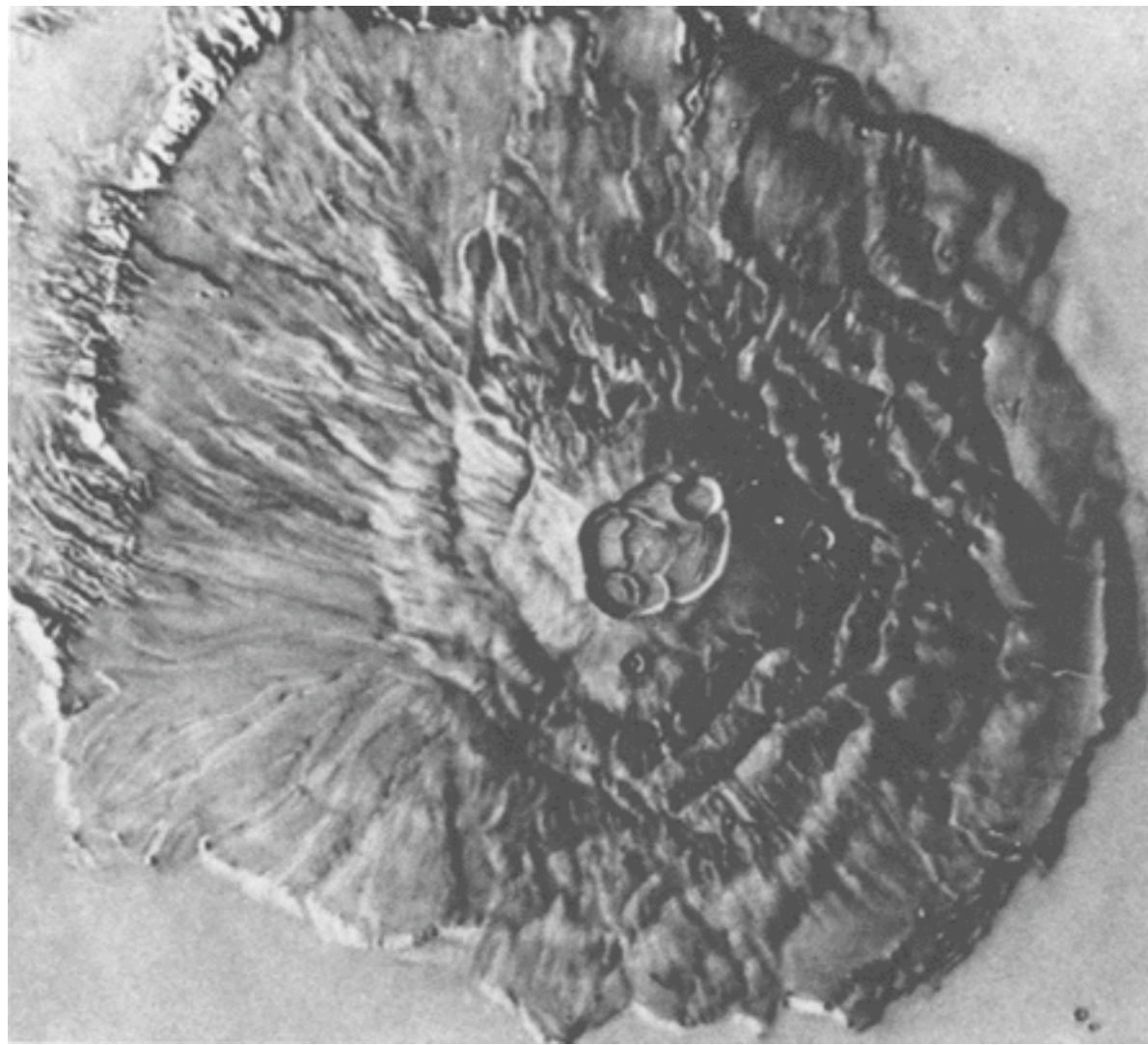
Space exploration

Mariner 4 (1965)

- Crater
- Desert



Mariner 9 (1972)

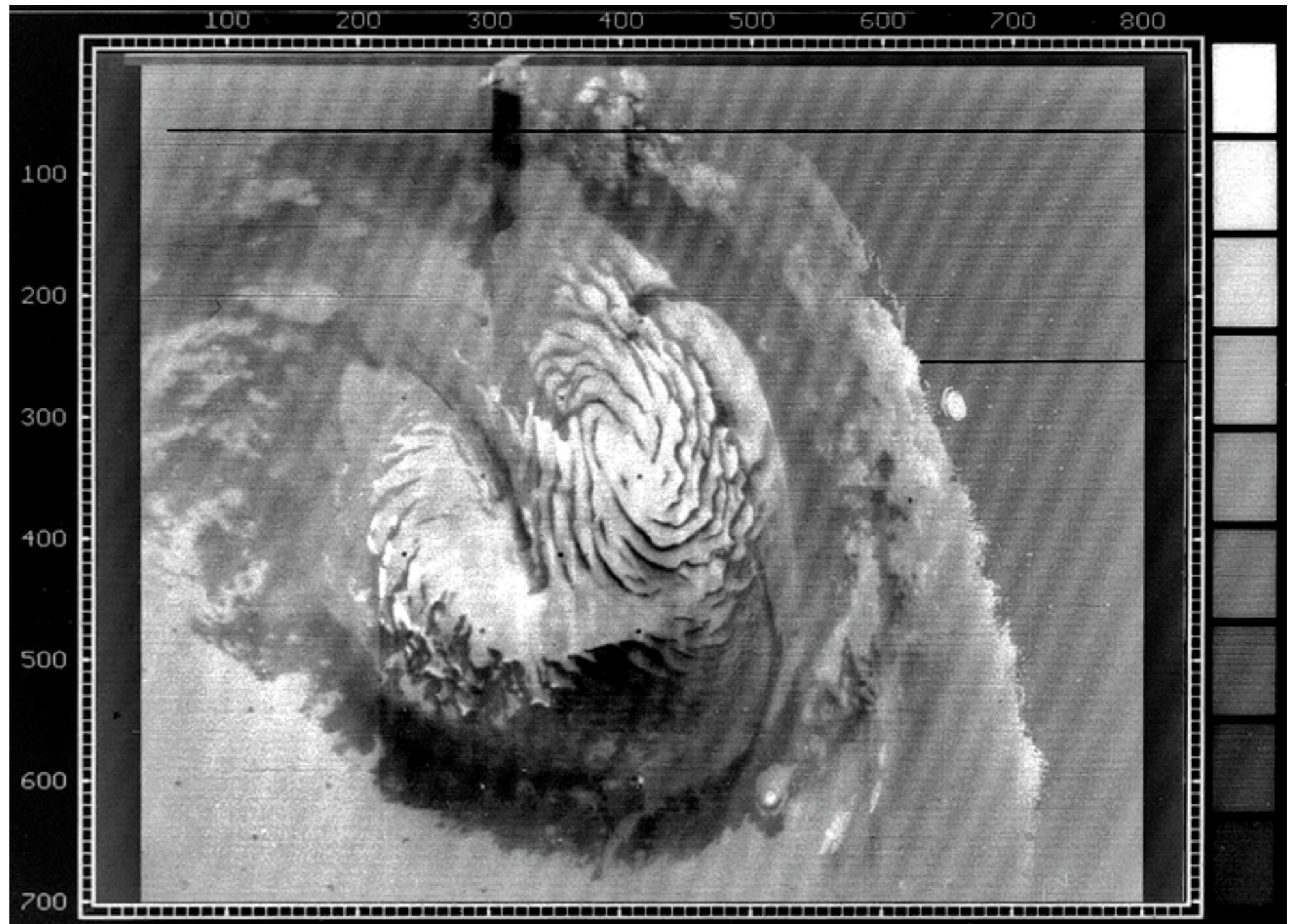


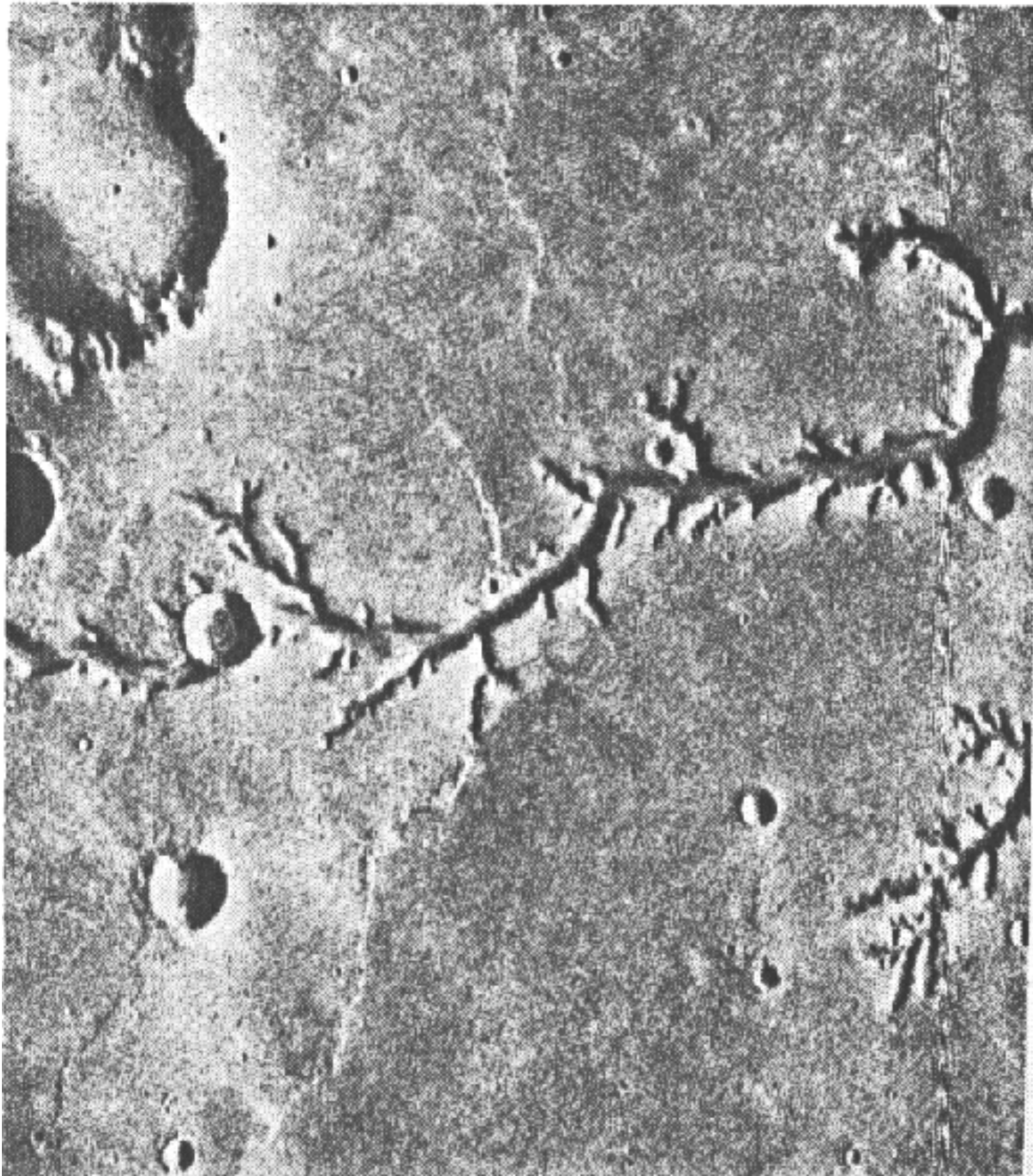
- Olympus Mons
- Volcan Hawaiian type volcano (25 km high)
- Inactive



Mariner 9 (1972)

- Polar cap
- Water ?



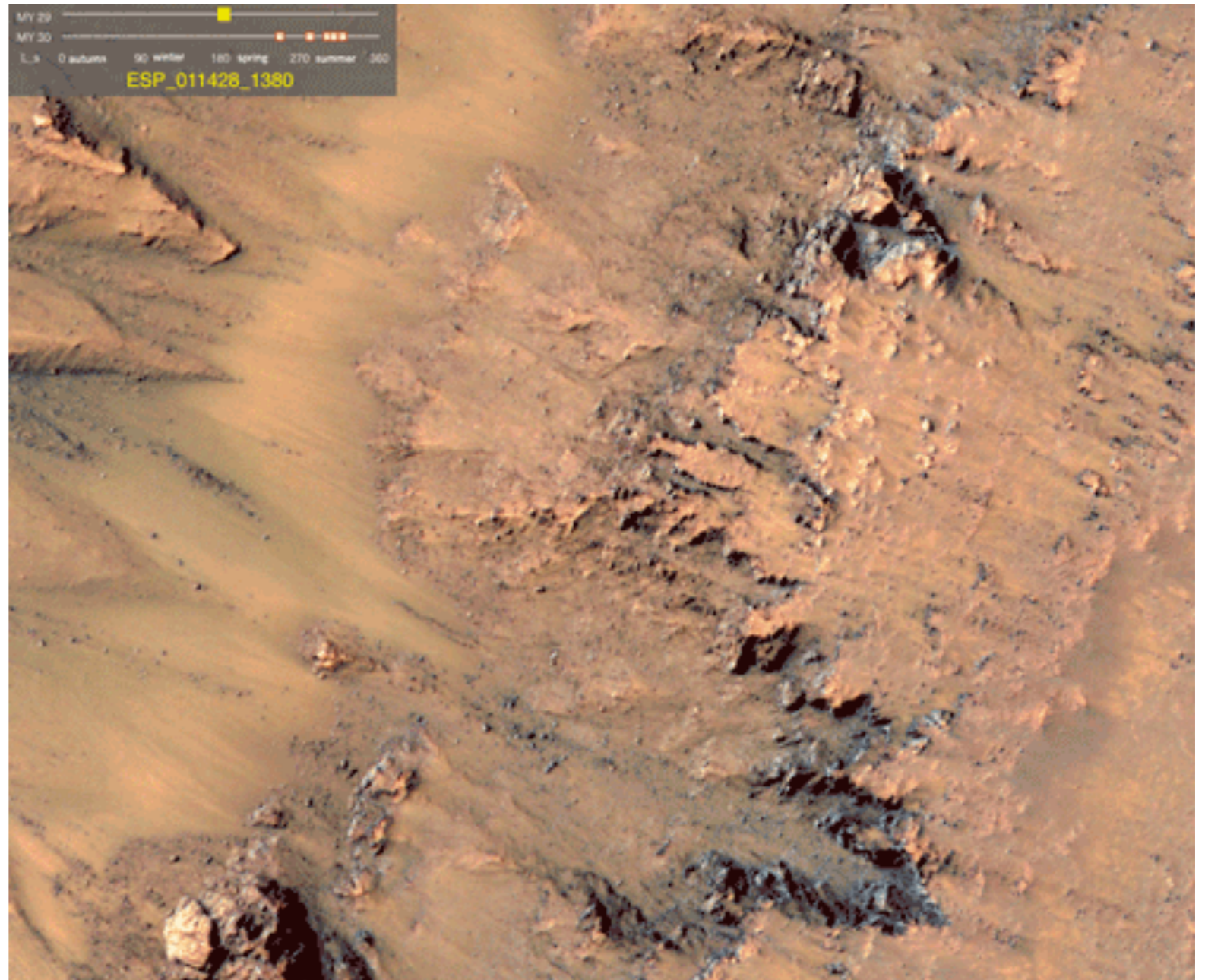


Mariner 9 (1972)

- Dendritic valley network
- Liquid water in the past ?

Mars Reconnaissance Orbiter (2011)

- Present time active flow
- Summer at mid-latitude ($\sim 30^{\circ}\text{S}$)
- Water ? brines ?
- Photophoretic effect ?

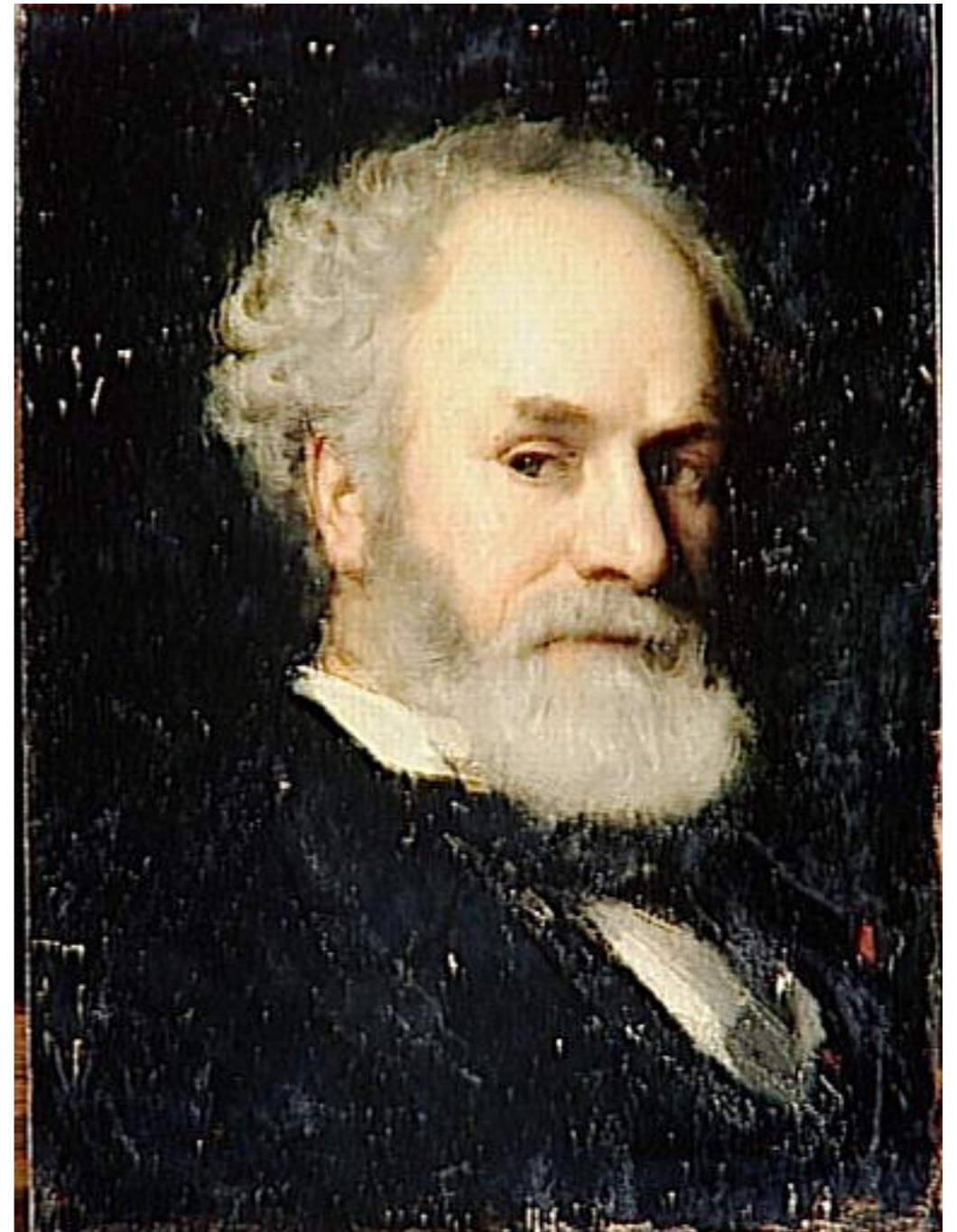


A grayscale image of a fingerprint is used as the background. The ridges and valleys of the fingerprint are clearly visible. Overlaid on this image is the word "Spectroscopy" in a large, bold, sans-serif font. The text is semi-transparent, allowing the fingerprint patterns to be seen through the letters. The word is centered horizontally and vertically on the page.

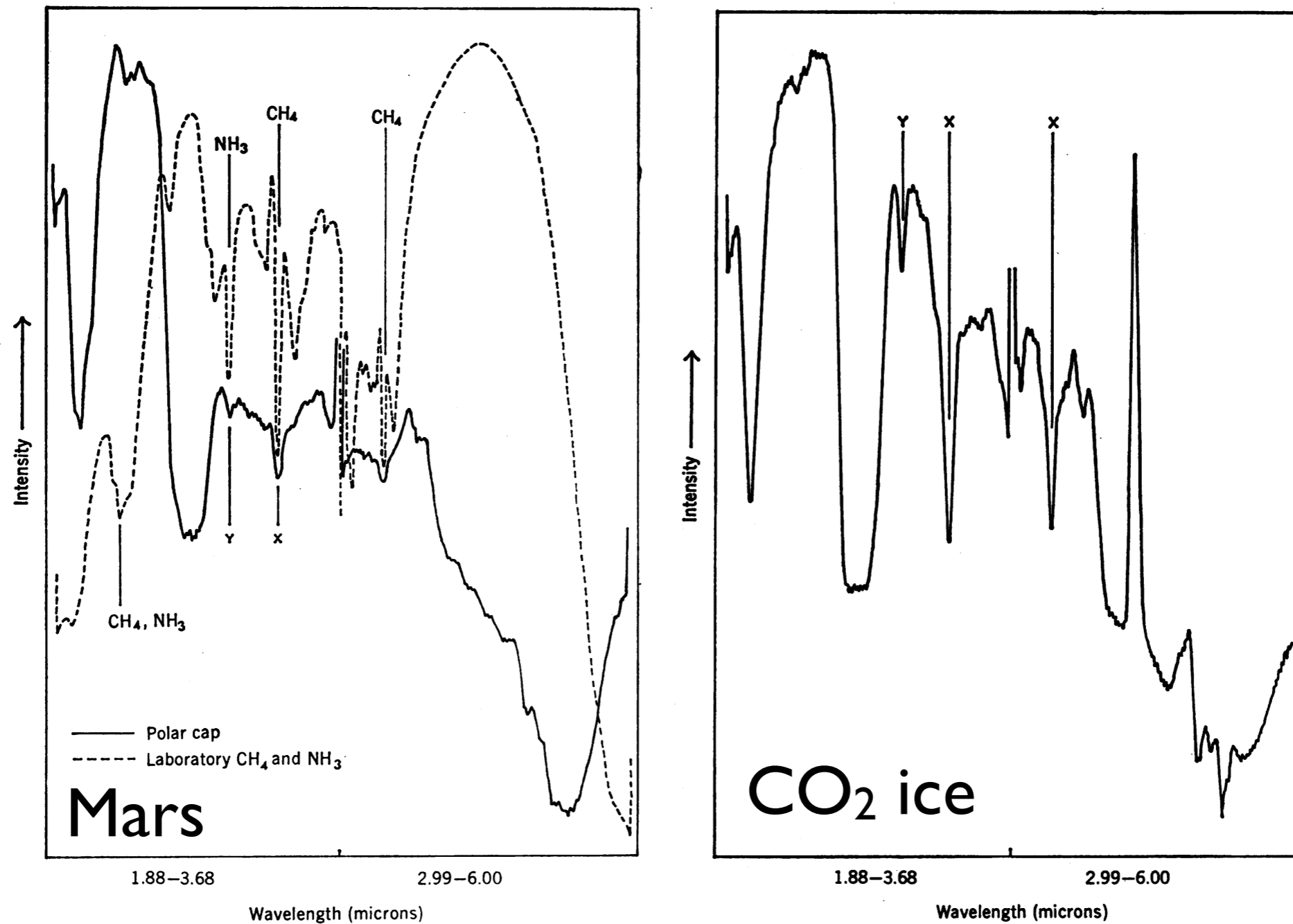
Spectroscopy

Spectroscopy from ground

- Jules Janssen, 1867 : Mont Etna
 - Water vapor on Mars
 - No atmosphere on the Moon
- Approximative Earth atmosphere correction



Spectroscopy from orbit



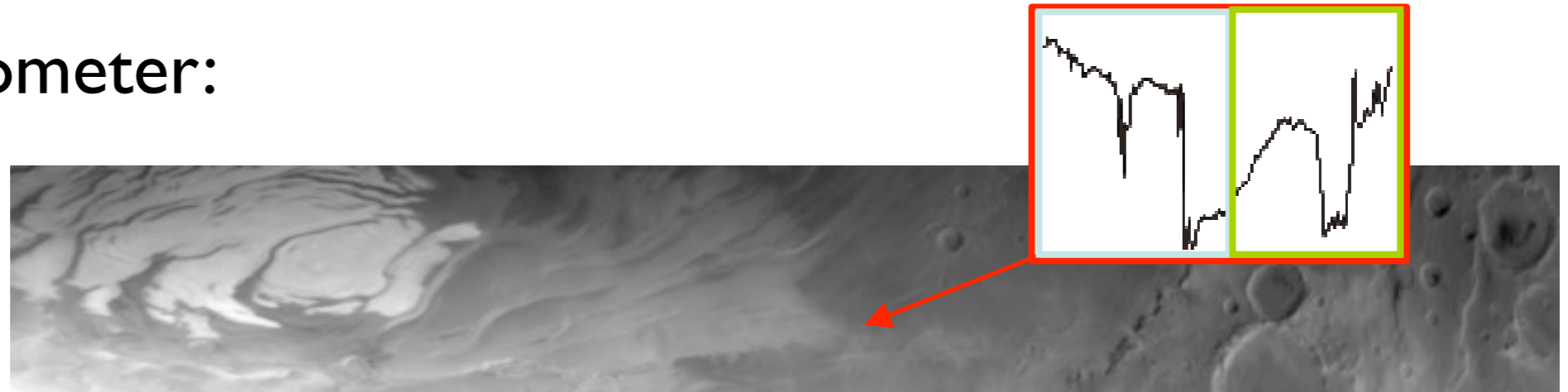
- Mariner 7
- First spectroscopic evidence of CO₂ ice



Hyper spectral images

Hyperspectral instrument

Imaging spectrometer:



OMEGA Near infra-red :

- C Detector between 1 and 2.6 microns
- L detector between 2.6 and 5 microns

Bibring et al., 2004

Spatial sampling : ~ 1 km

Spectral sampling : 0.01 microns

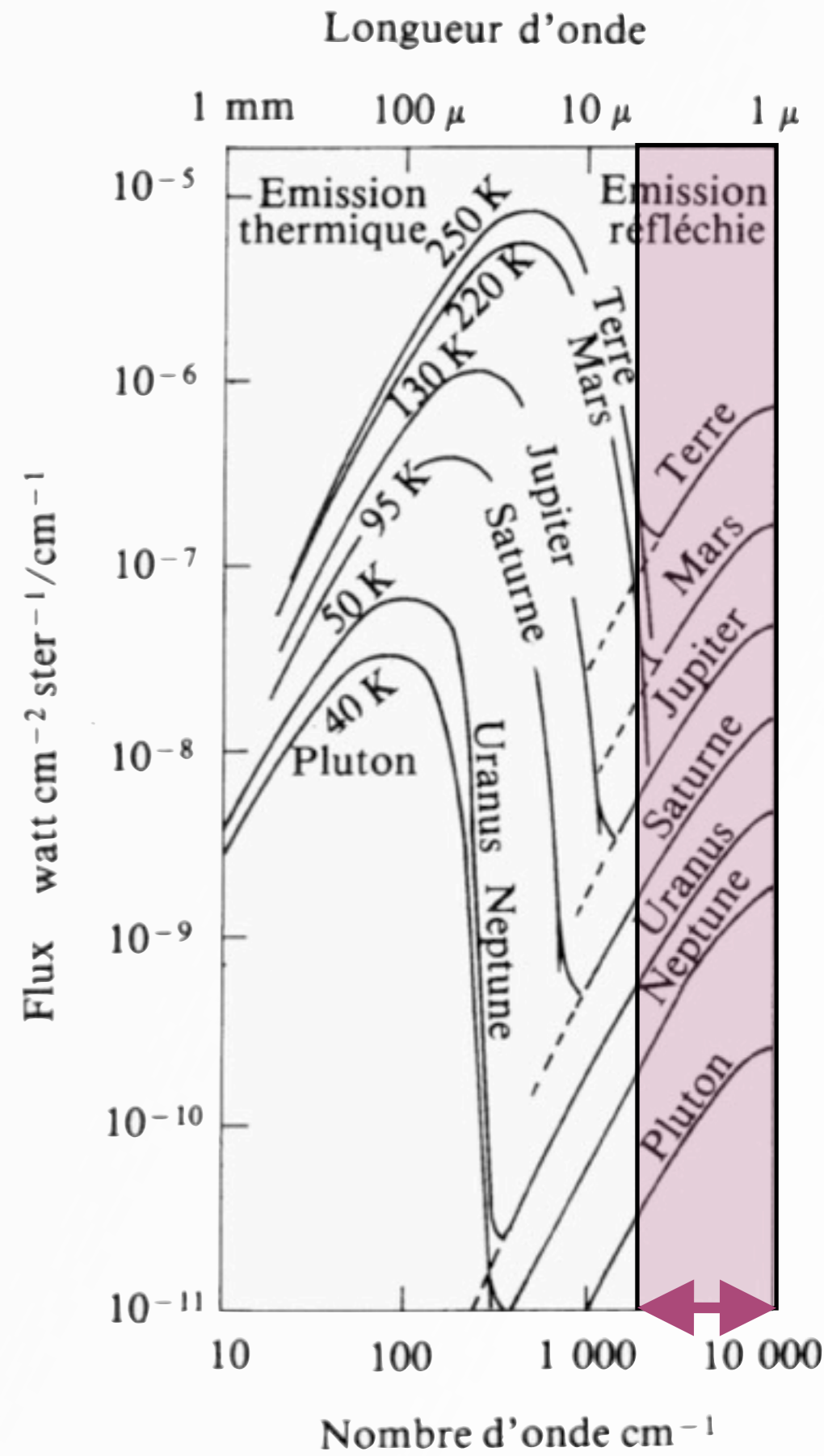
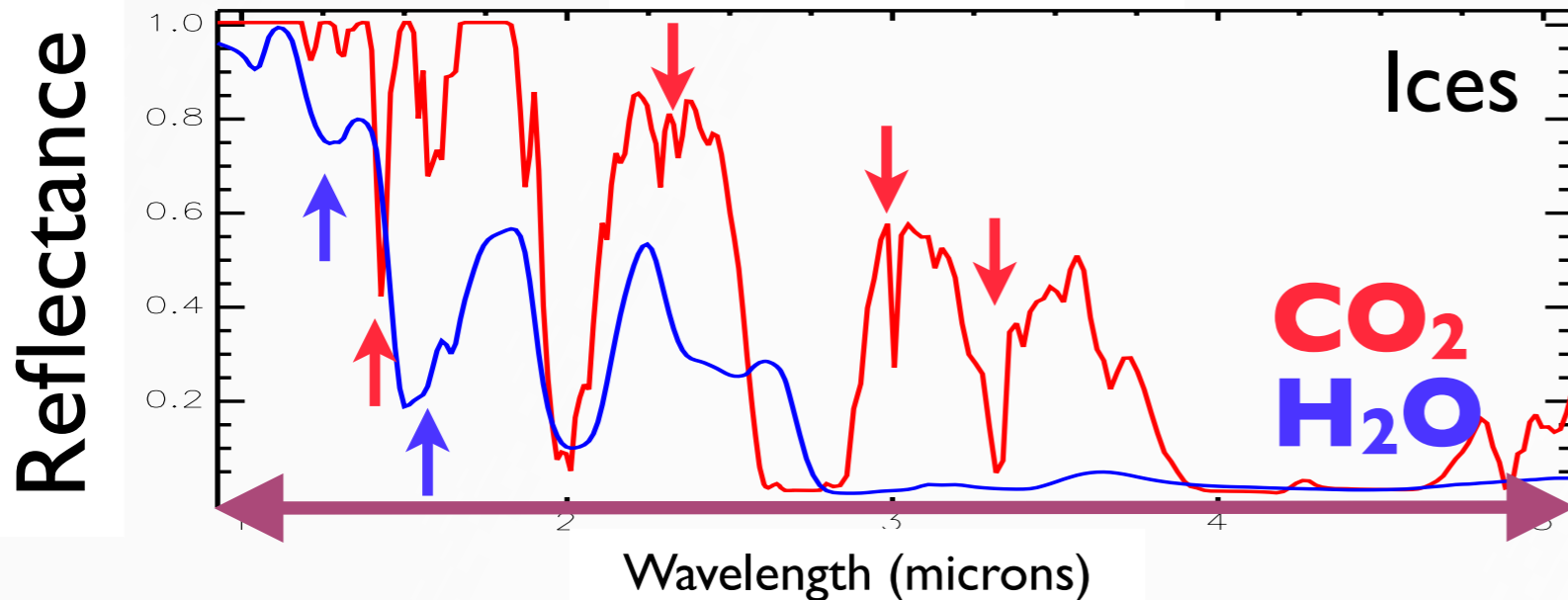
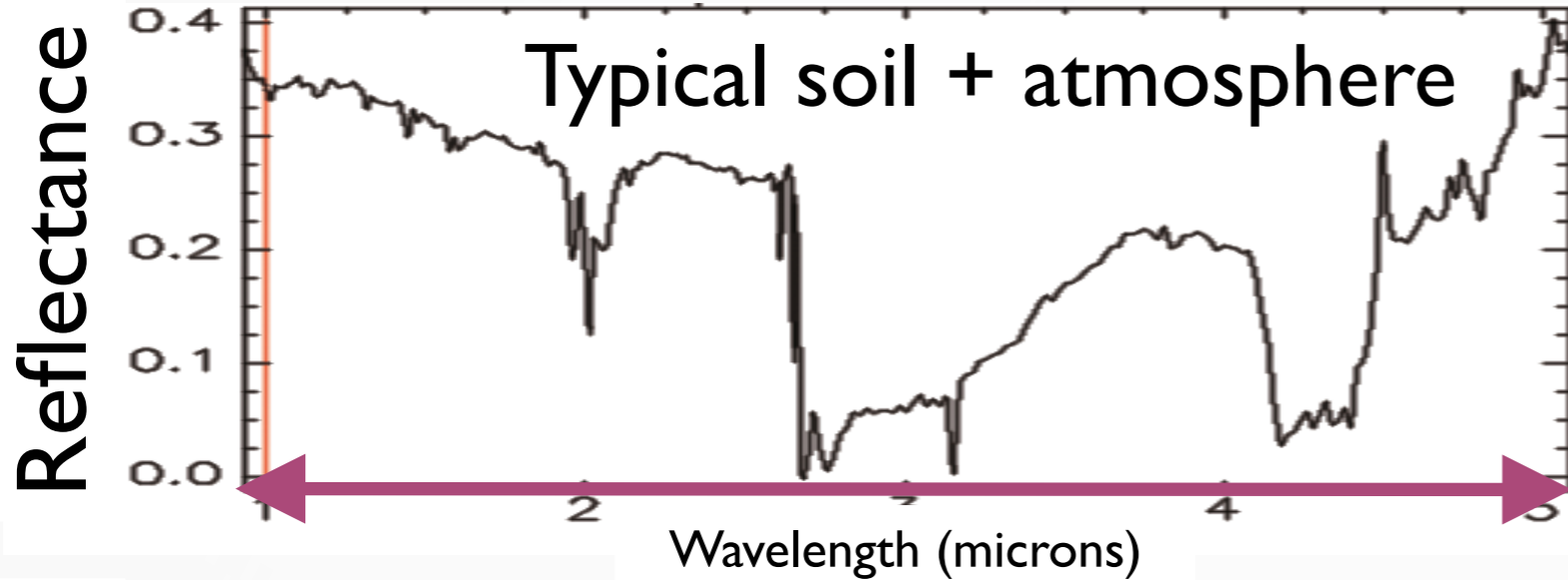
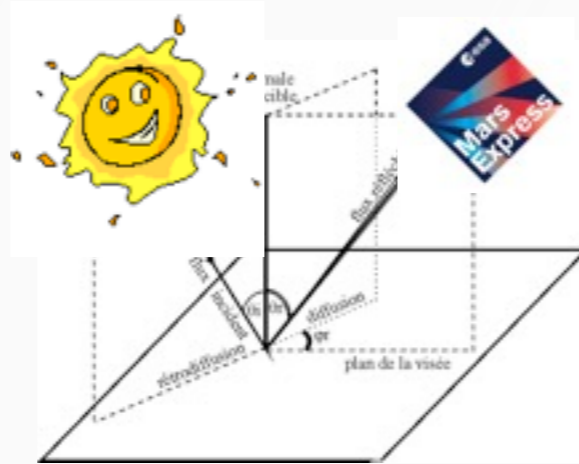


**DATASET : 1000 Cubes of
256 spectels, 256 lines * 2000 columns = 500 000 pixels each**

The NIR signal

Contribution :

- atmosphere
- surface





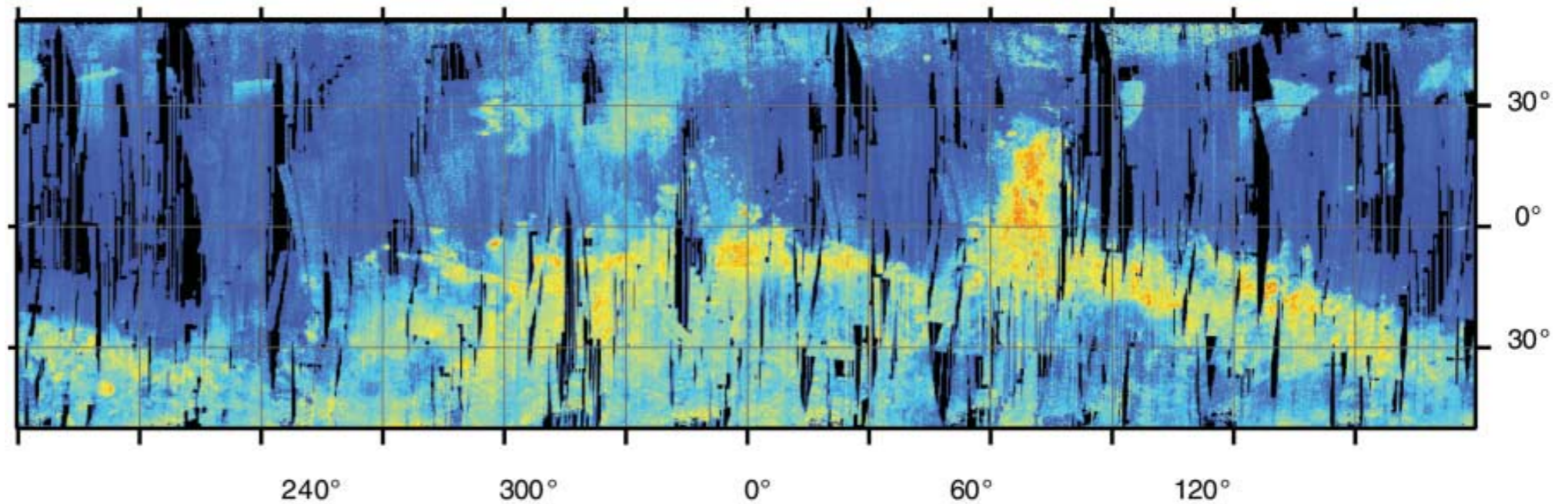
Hyperspectral images

1. Mapping the composition

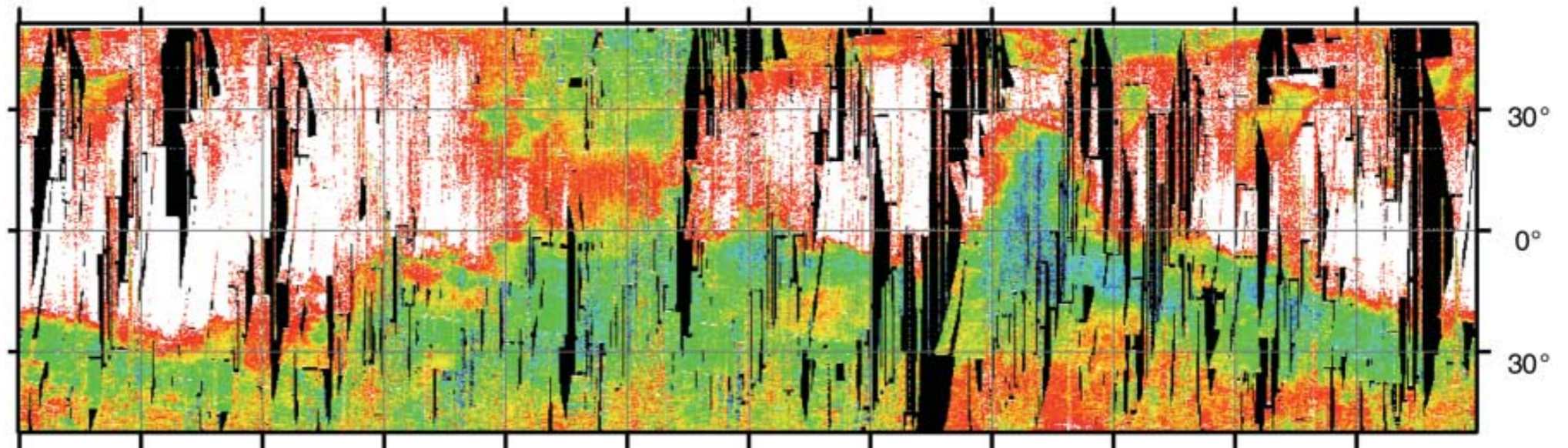
2. Mapping the physical state

Mineral Mapping

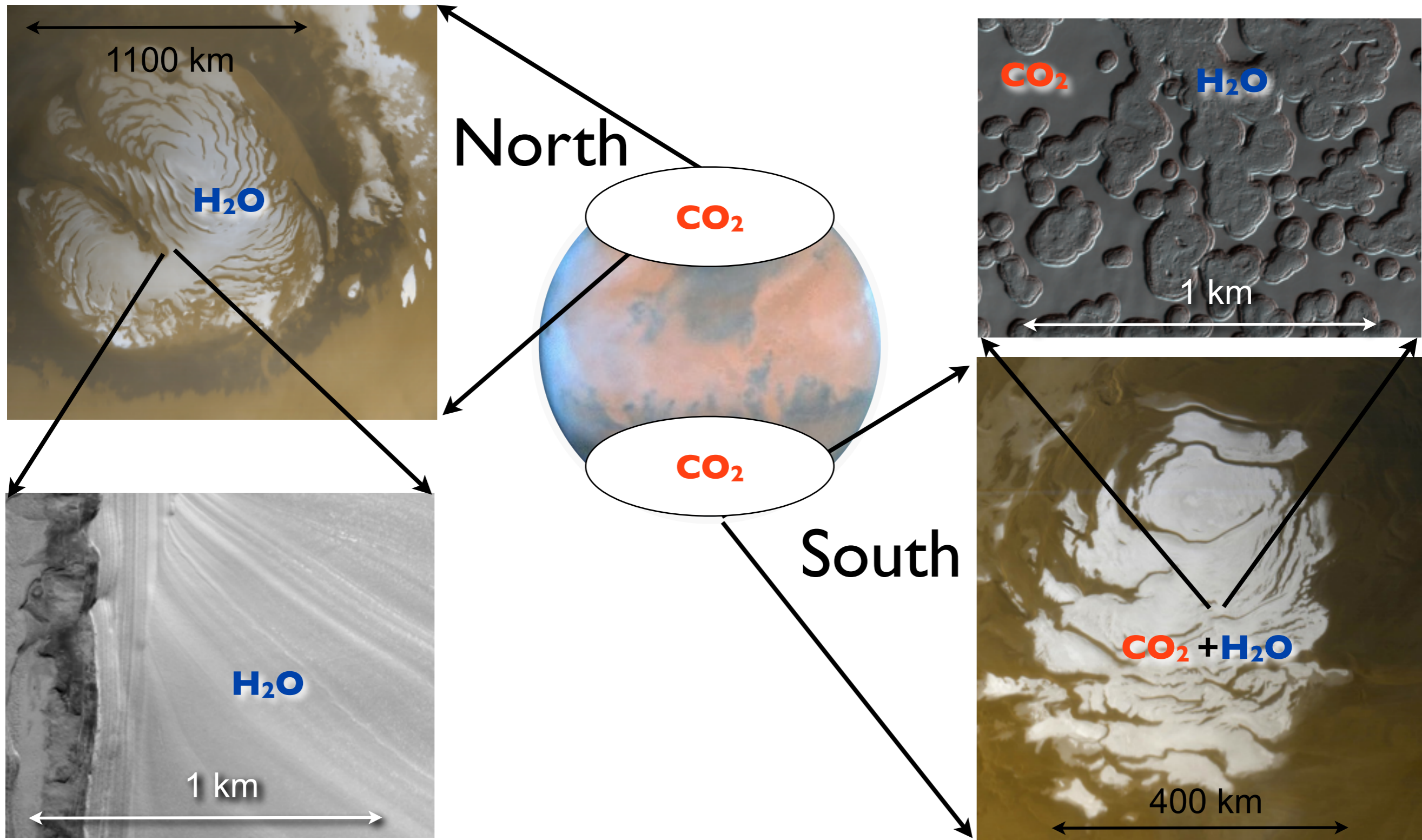
- pyroxene

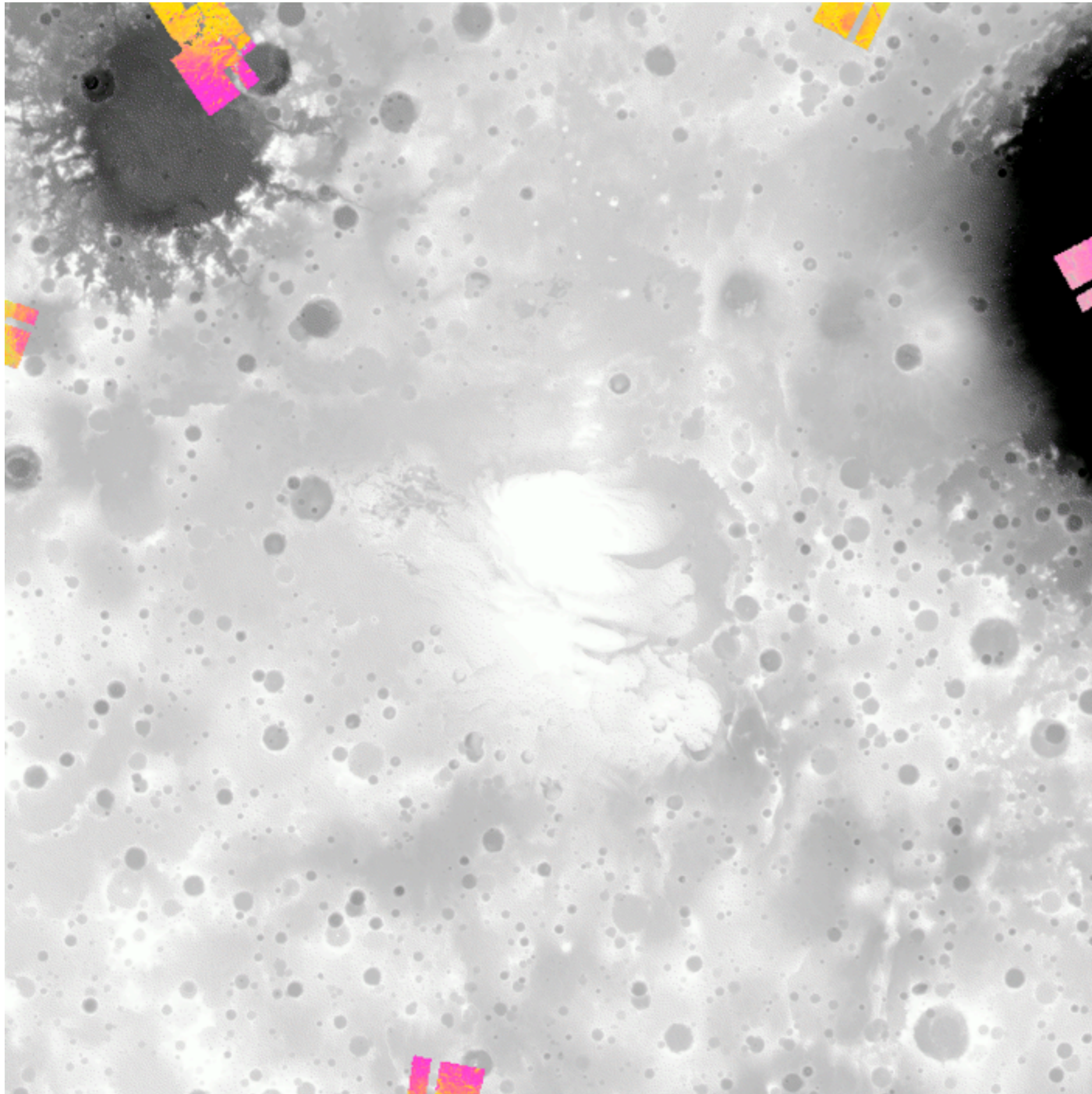


- ferric
nanophase
oxides



Residual Martian caps





Mapping CO₂ and H₂O

Seasonal
South Polar
Cap recession
in 2005

Schmidt et al., TGRS 2007
Schmidt et al., Icarus 2009



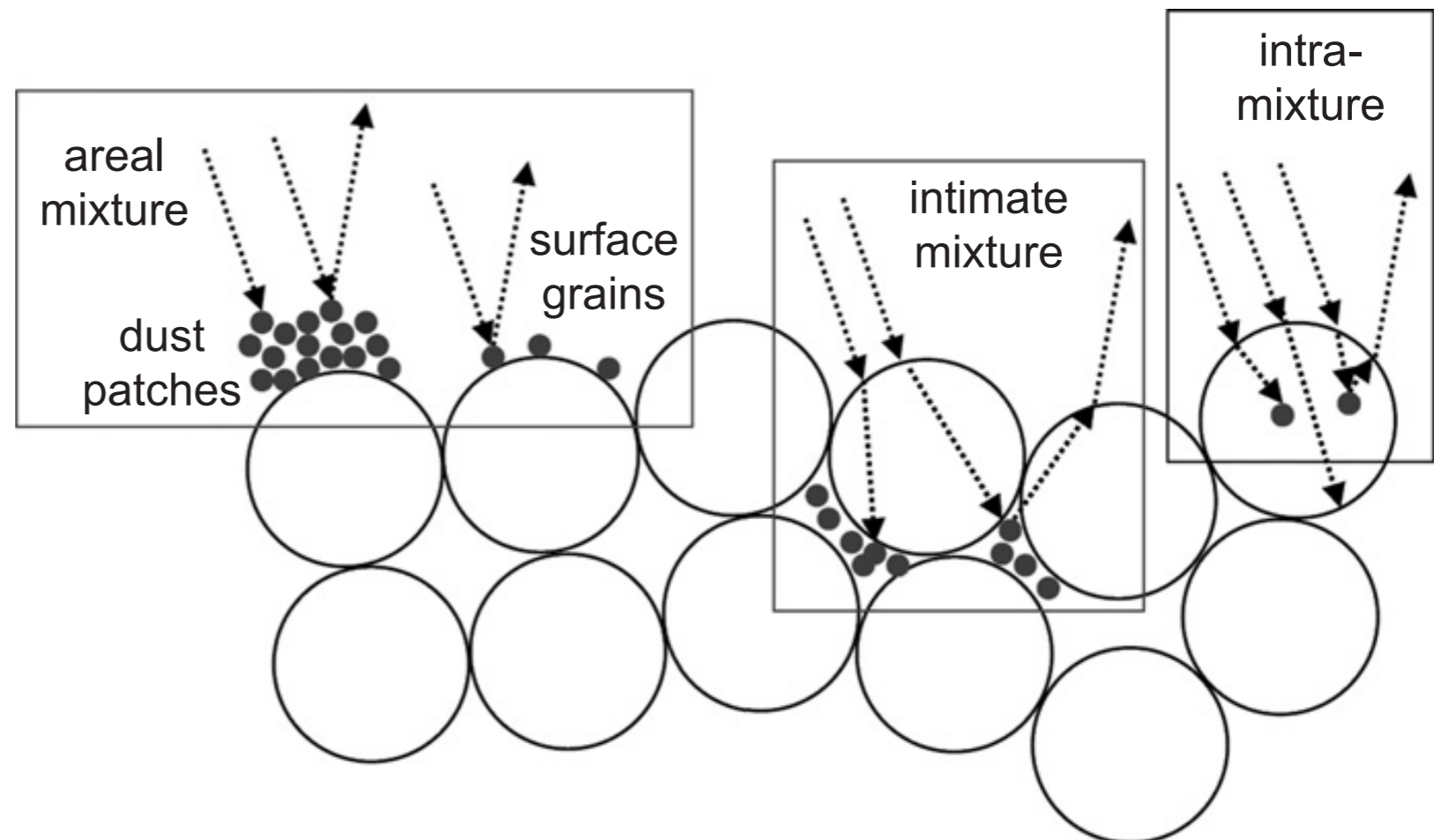
Hyperspectral images

1. Mapping the composition

2. Mapping the physical state

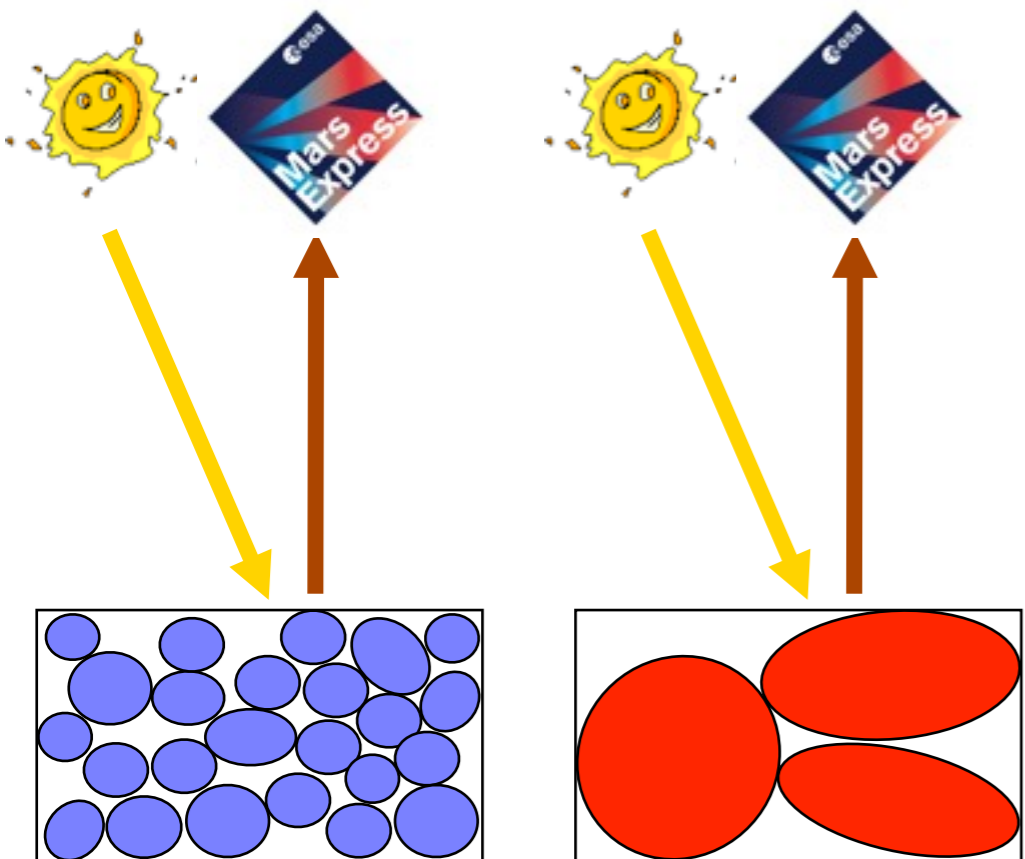
Mixing mode ?

- areal
- intimate
- intra-grain

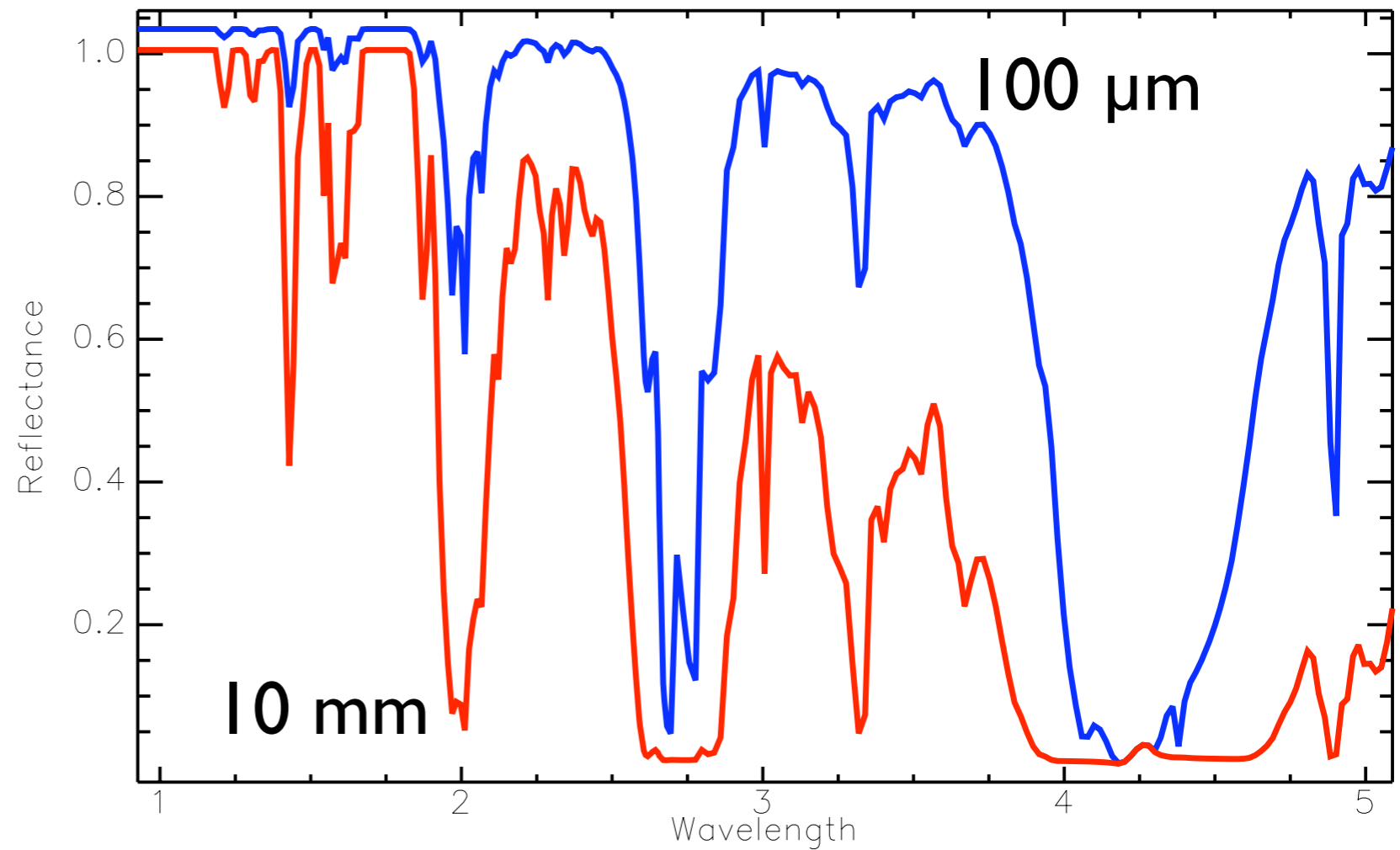


Spectral shape = physical state

Grain size \sim free mean path

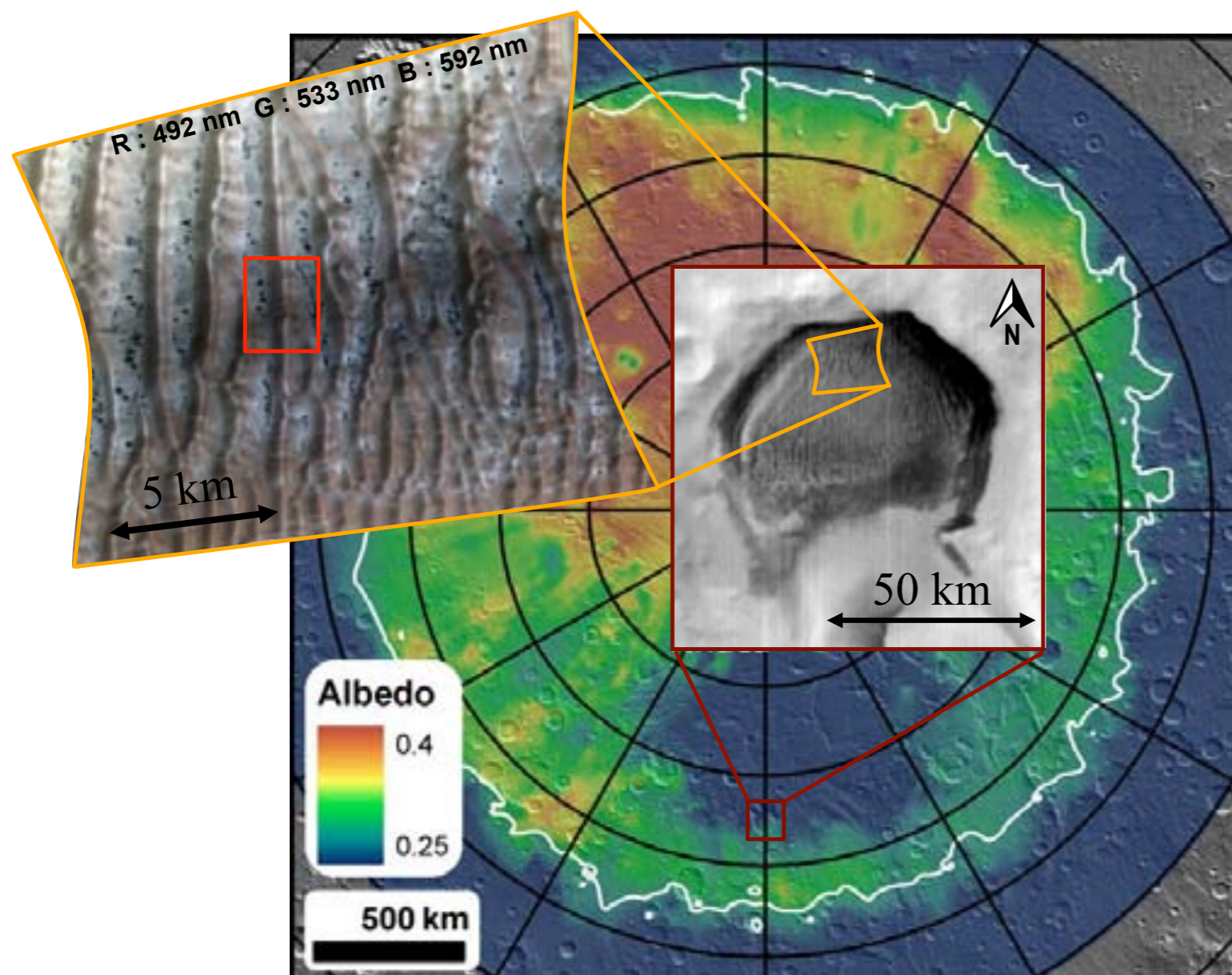


Douté, et al, *JGR*, 1998

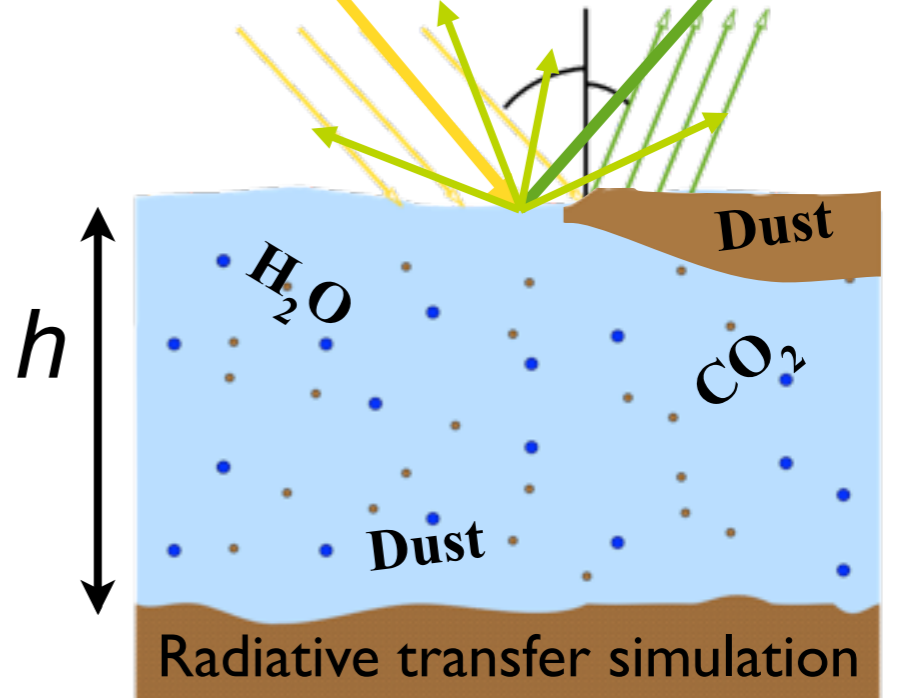


Schmitt, et al, *Solar System Ice*, 1998

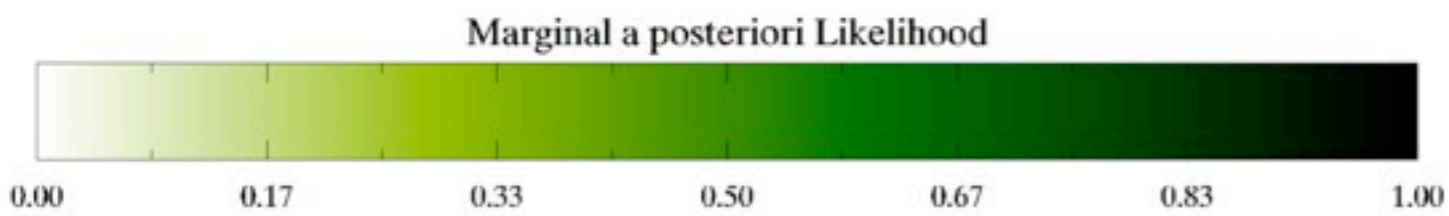
Example: Richardson



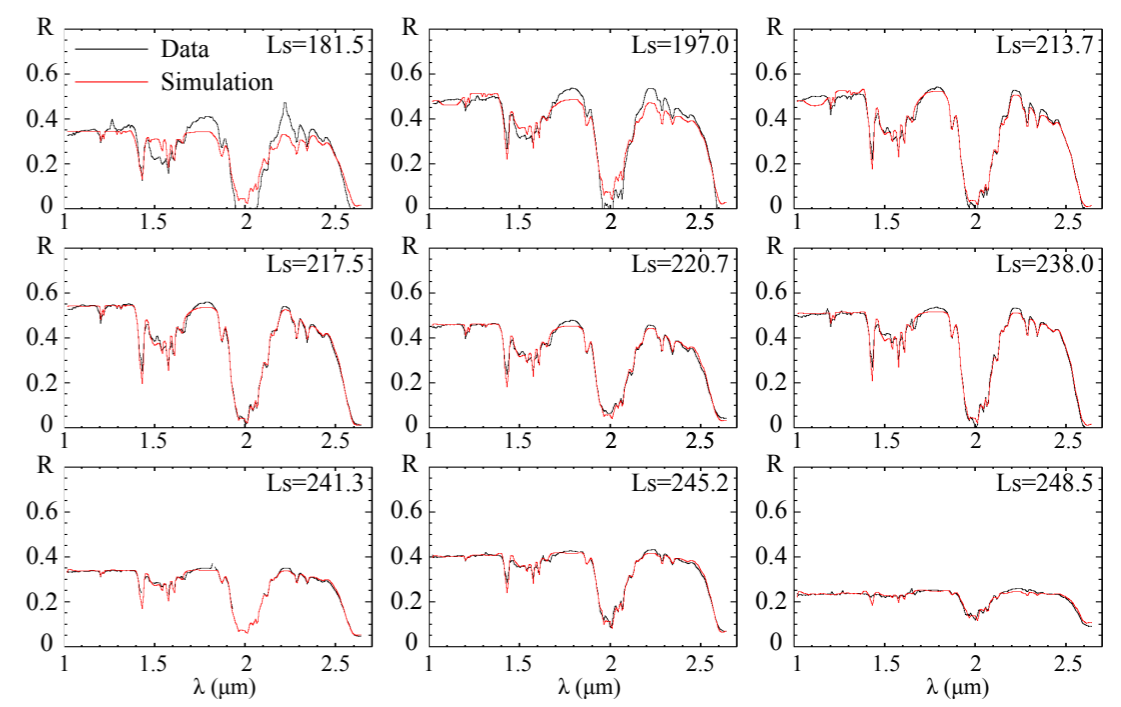
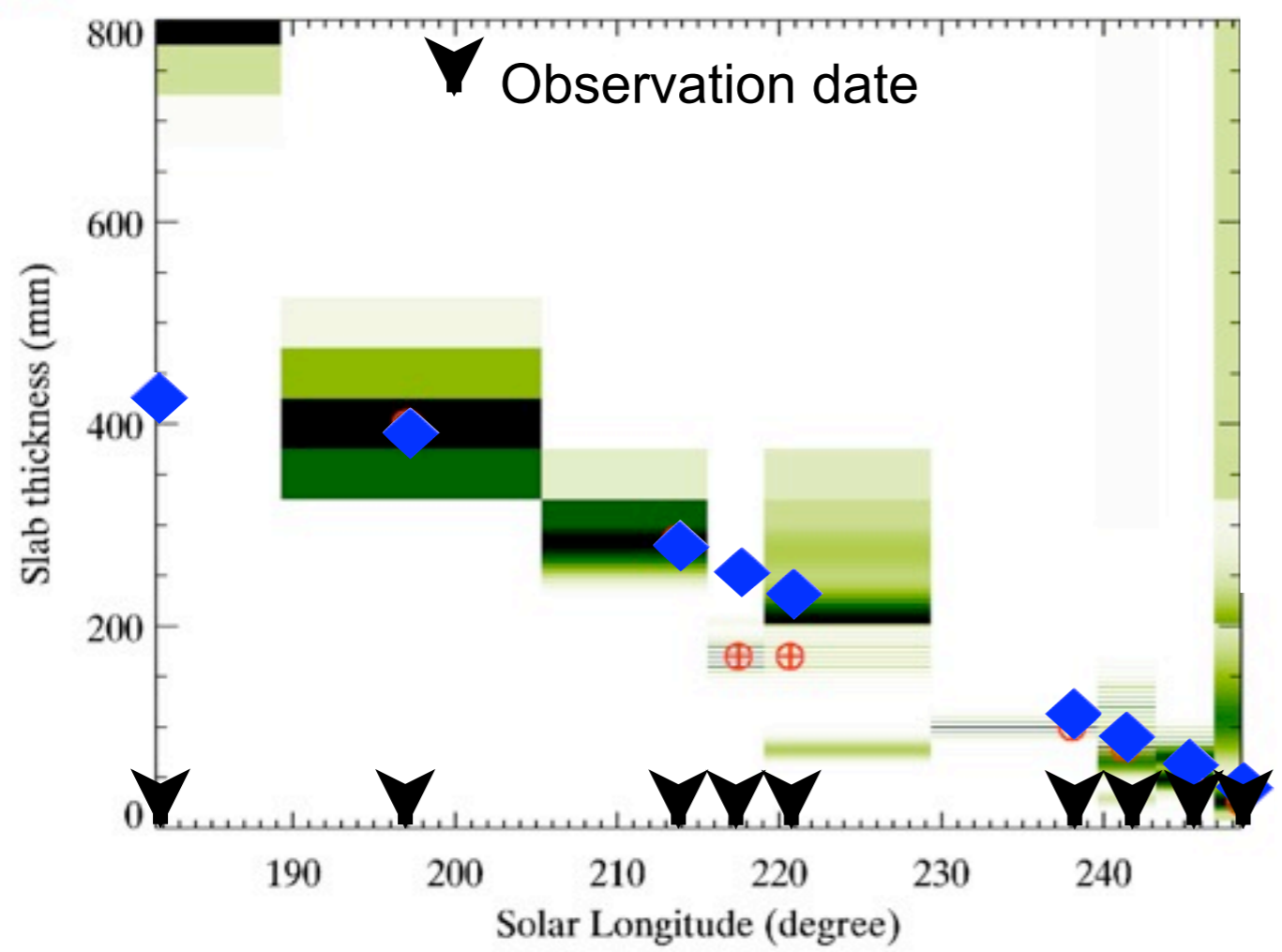
Richardson



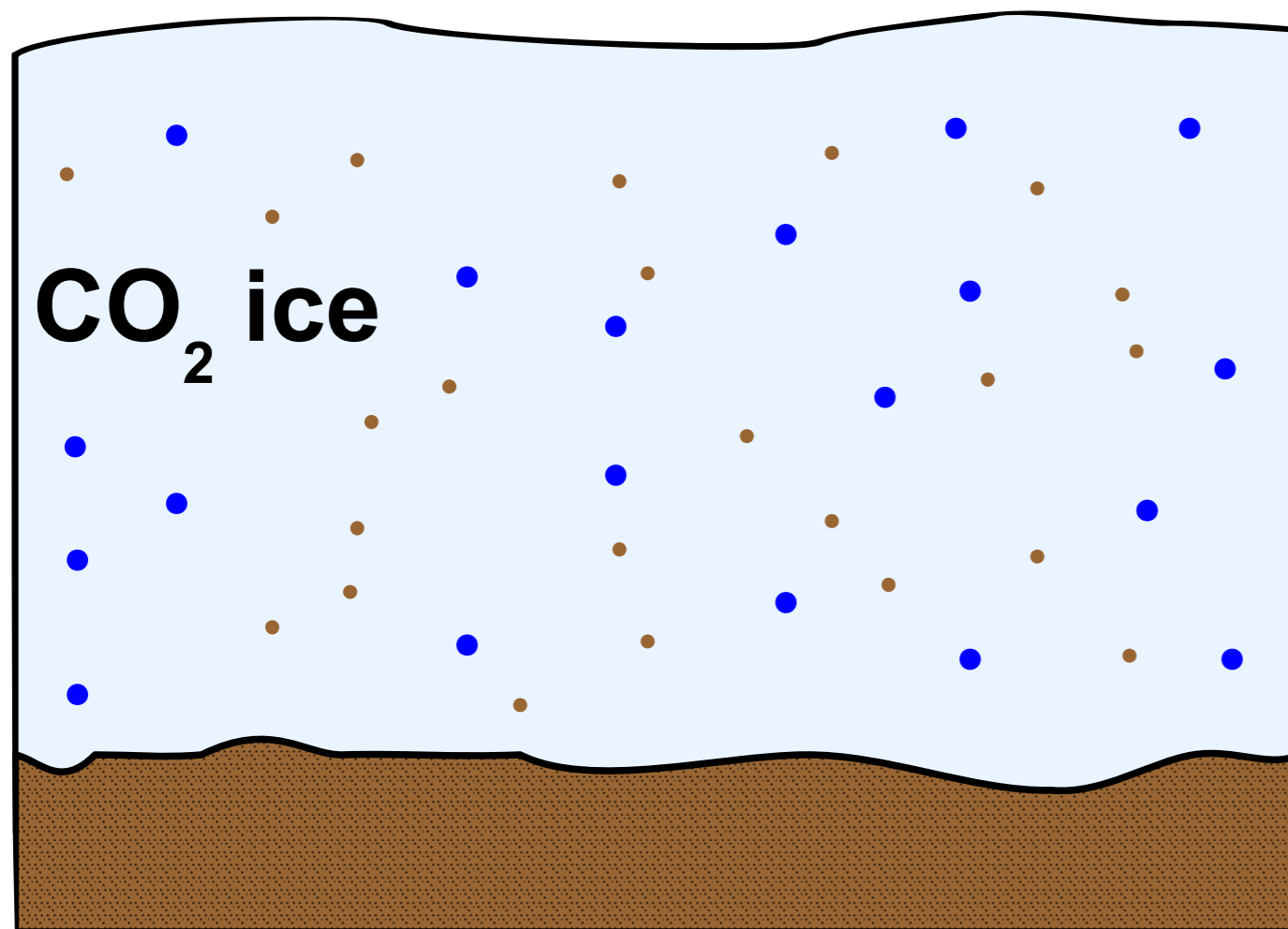
Andrieu et al., 2015



⊕ Maximum likelihood ◆ GCM predictions (Forget et al., 2006, Millour et al., 2014)

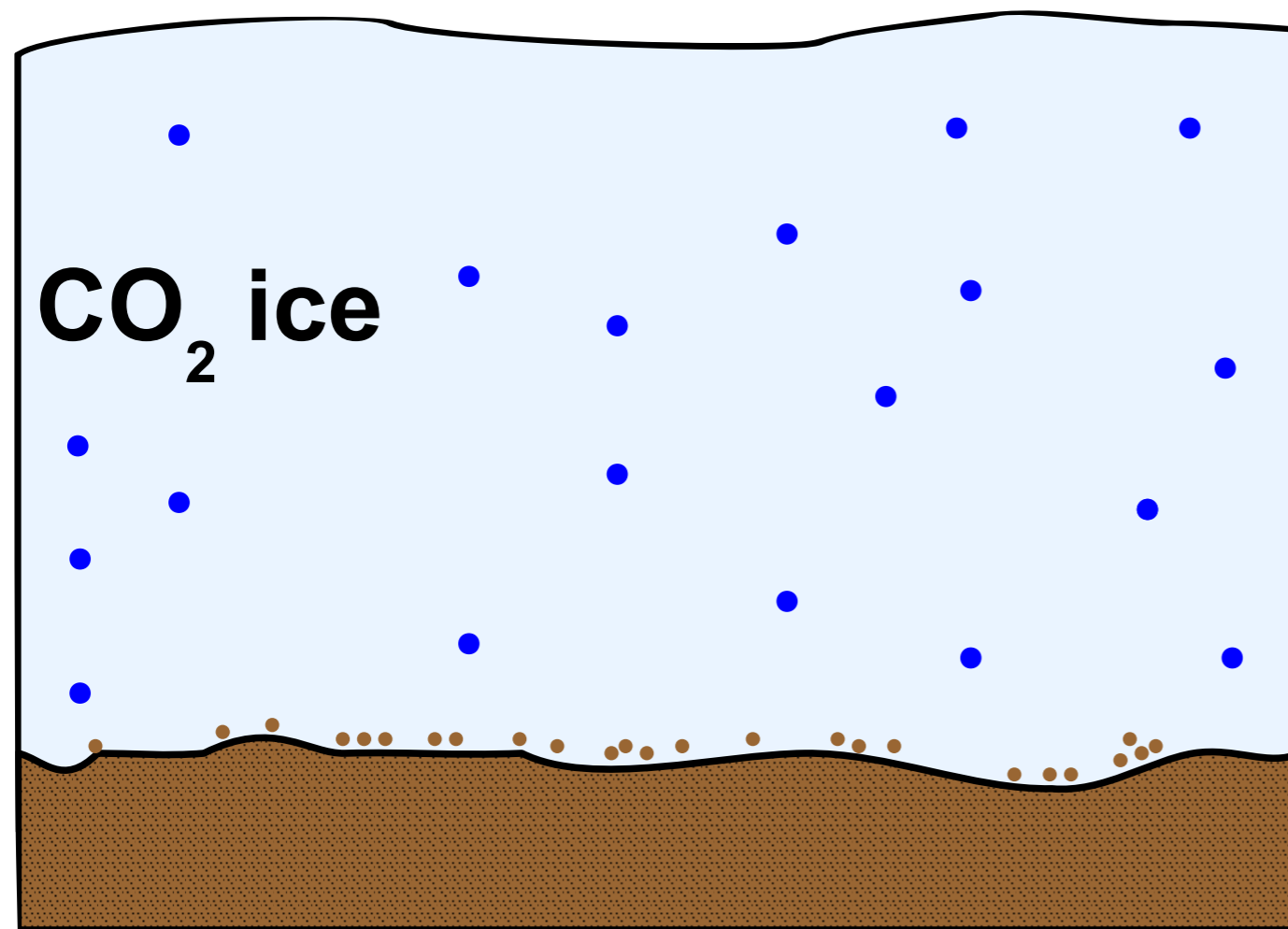


Scenario



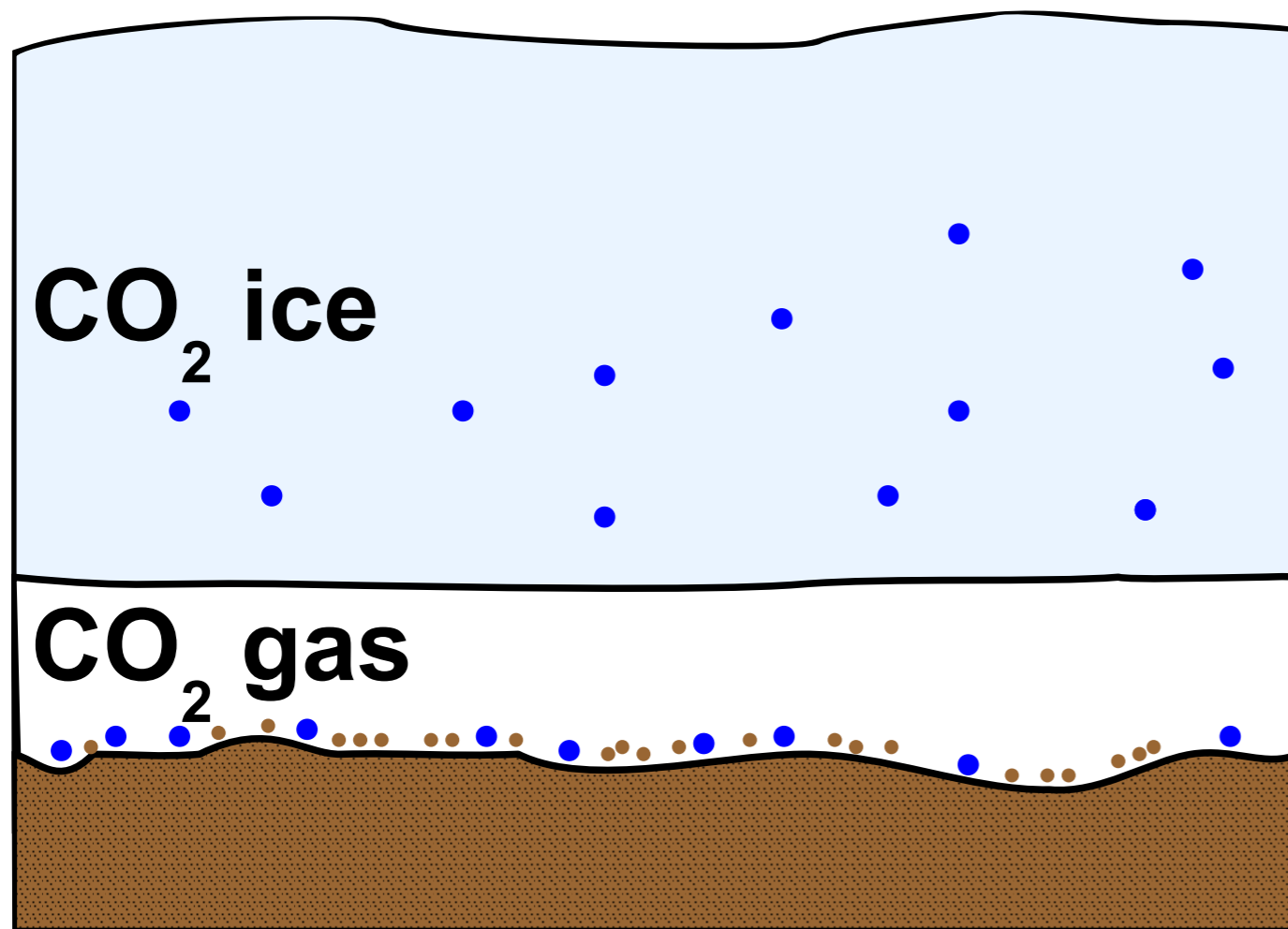
- CO₂ ice + dust + water ice

Scenario



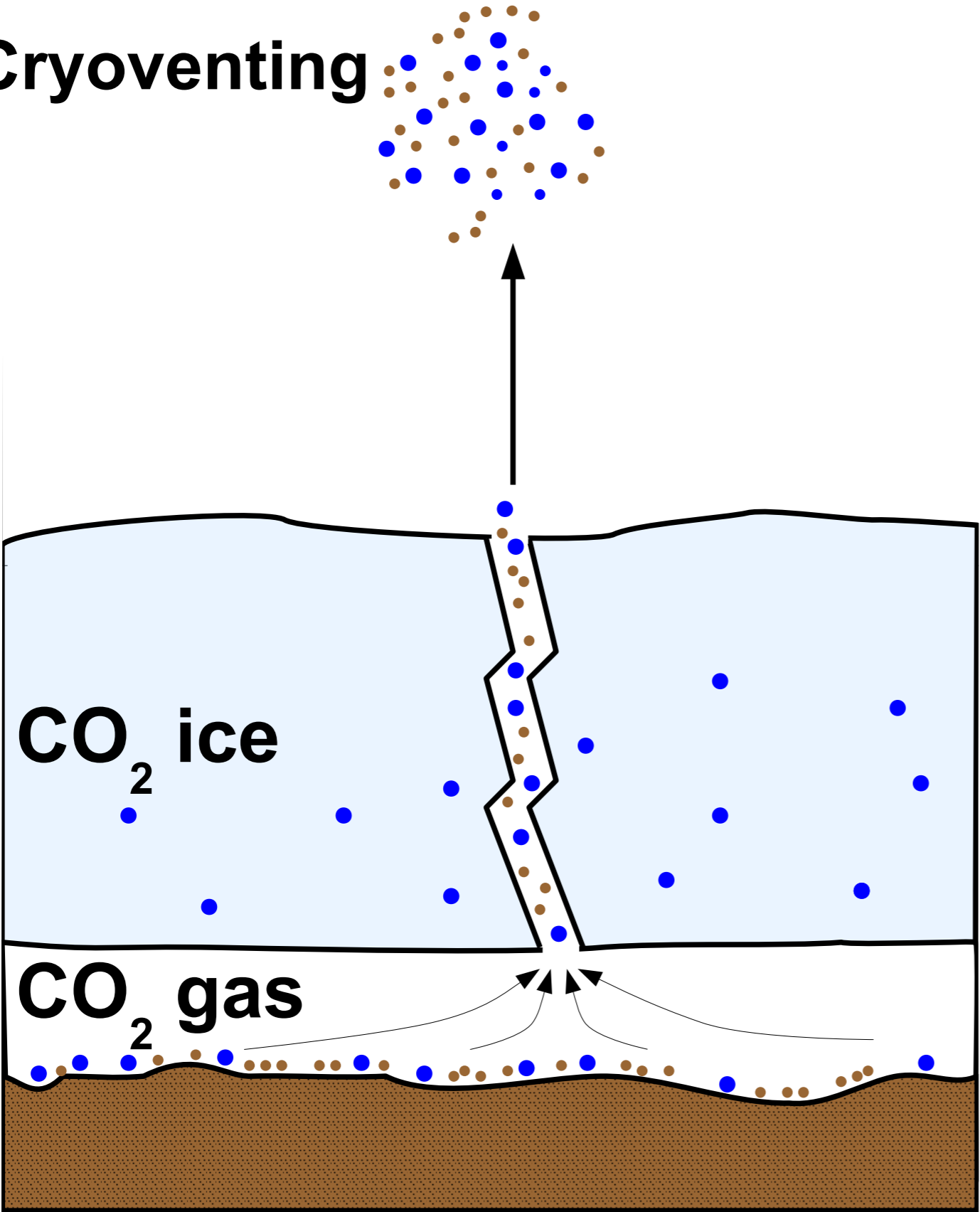
● Dust removal

Scenario

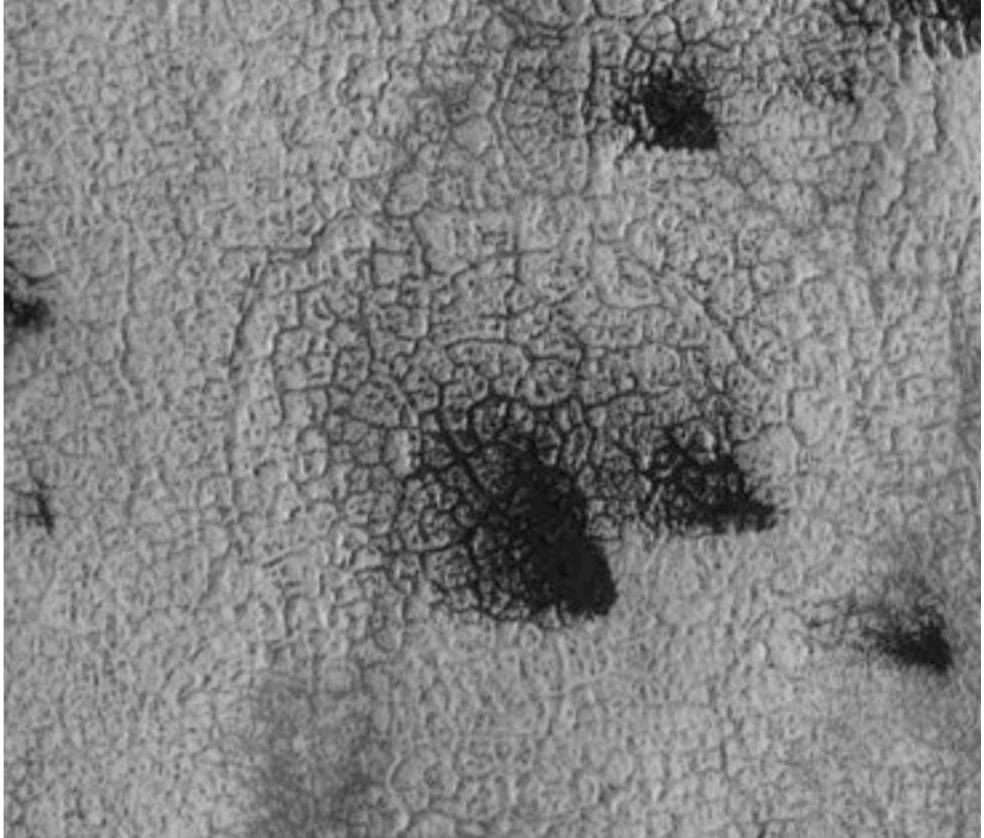


- Sublimation in the bottom

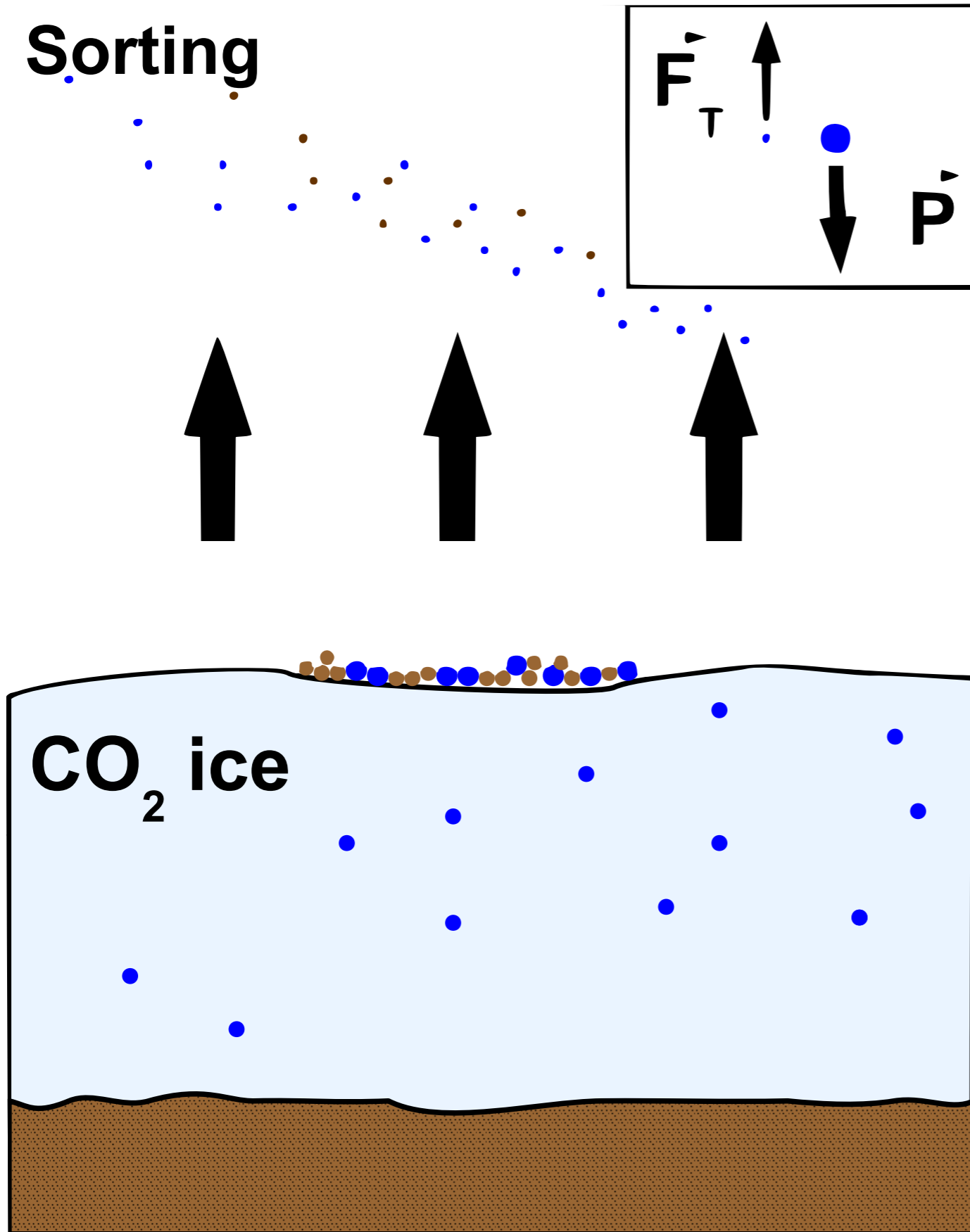
Cryoventing



● Jet



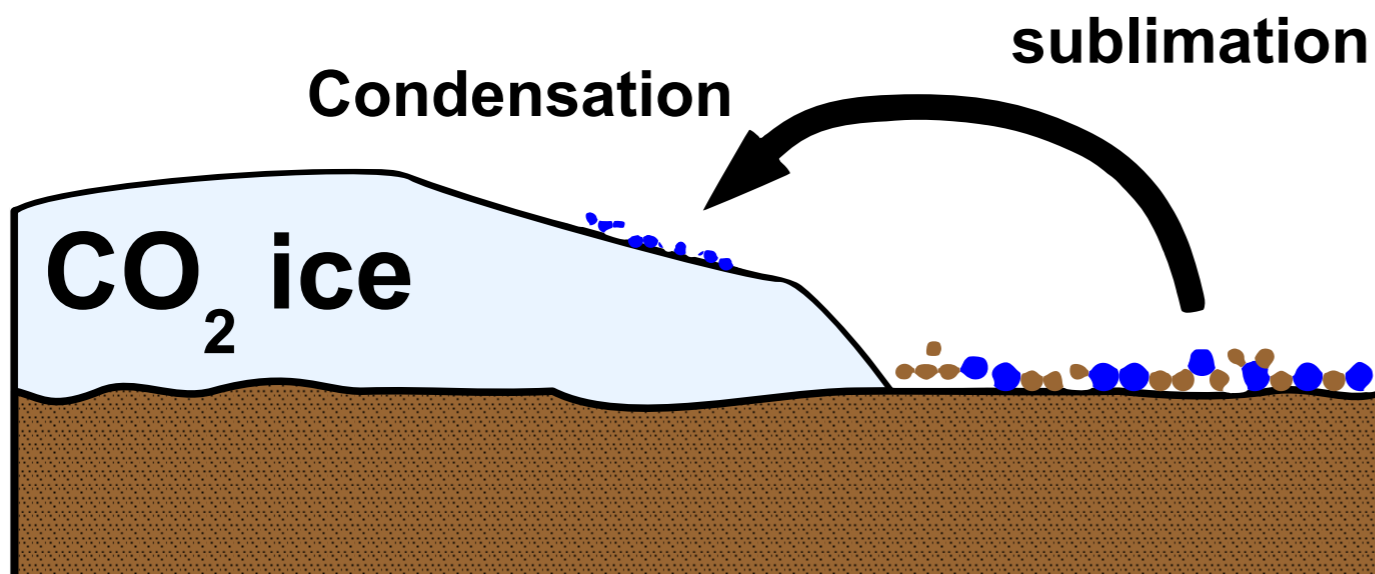
Sorting



● water source

Scenario

- Cold trap

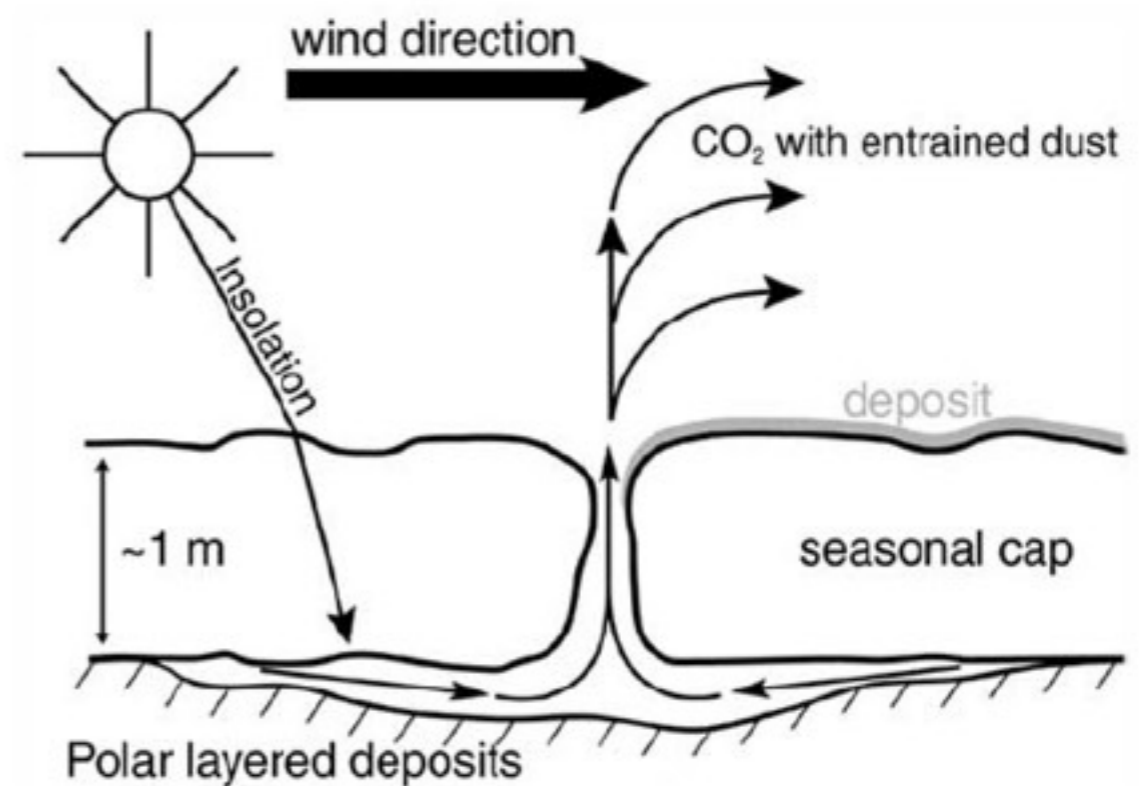


Geyser

Translucent slab ice in the SSPC:

- Almost everywhere
- Change in space and time
- Origin of the geyser?

Andrieu et al., 2018



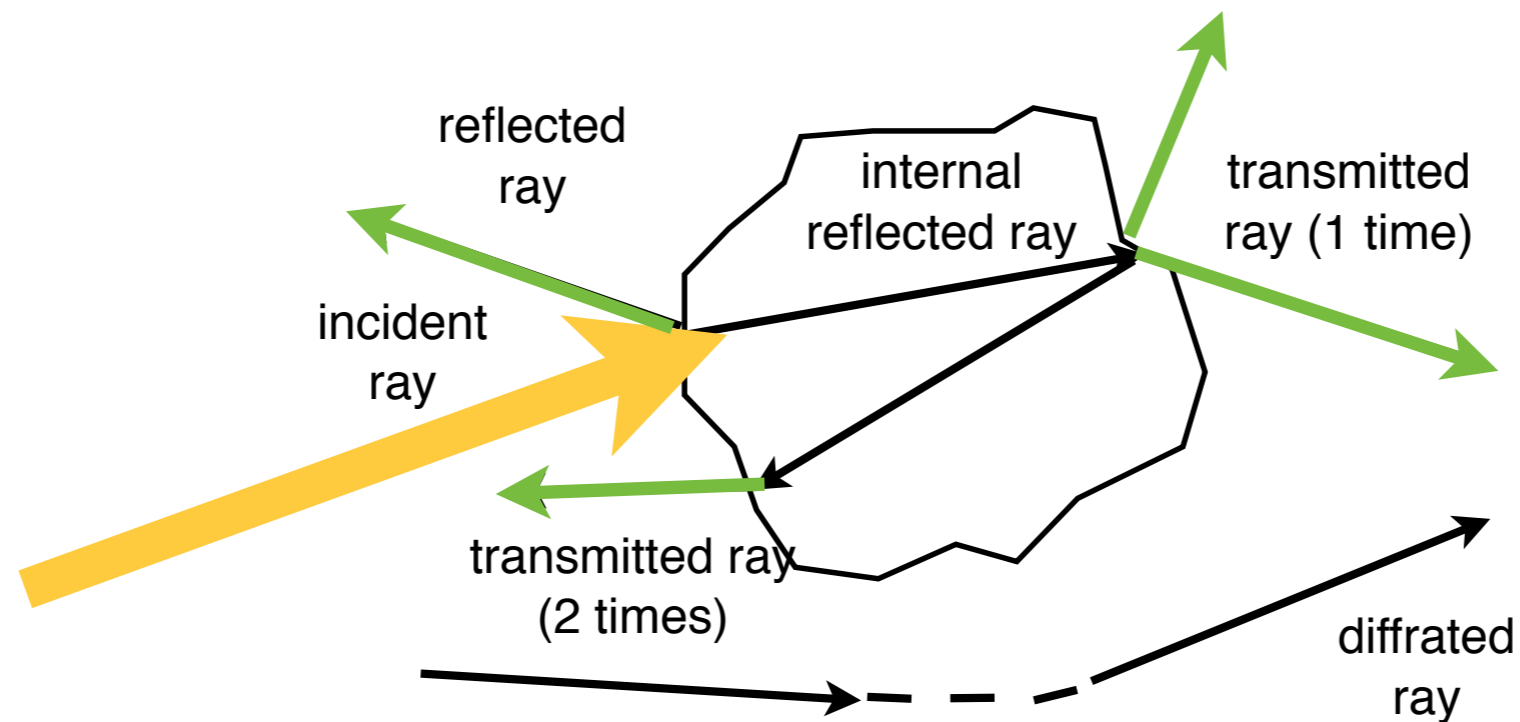
Kieffer, 2000 ; Piqueux, 2002 ; Kieffer, 2007



A grayscale image of a fingerprint, showing the intricate ridge patterns. The text "Multi angular images" is overlaid in a large, bold, sans-serif font, centered on the image. The text is semi-transparent, allowing the fingerprint details to be visible through it. The background is a high-contrast, textured surface, likely the skin of a finger, with various shades of gray and black, highlighting the ridges and valleys of the fingerprint.

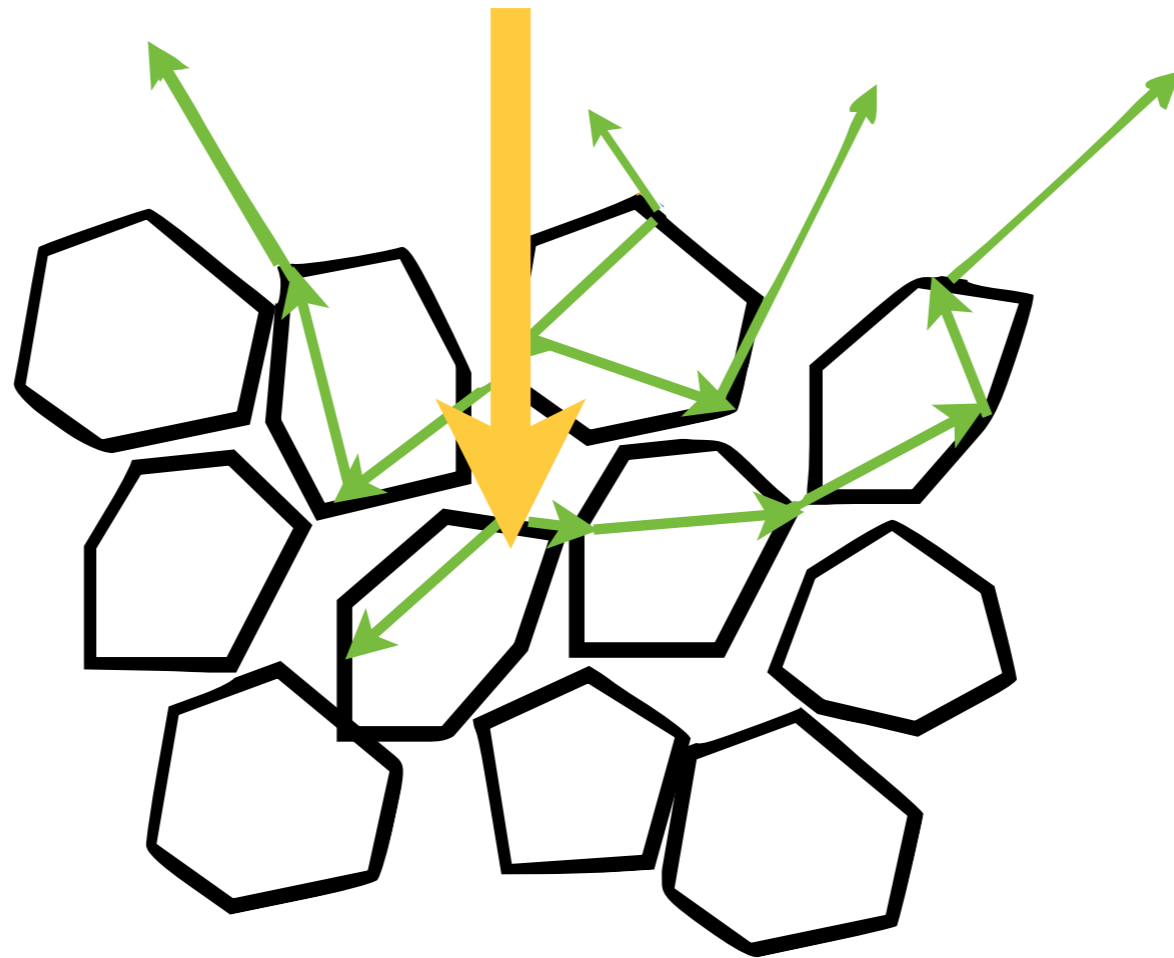
**Multi
angular
images**

One grain



- Multiples interactions: absorption, diffusion, diffraction

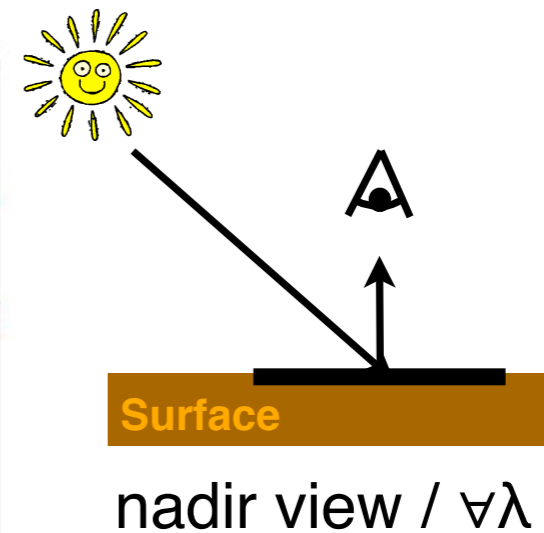
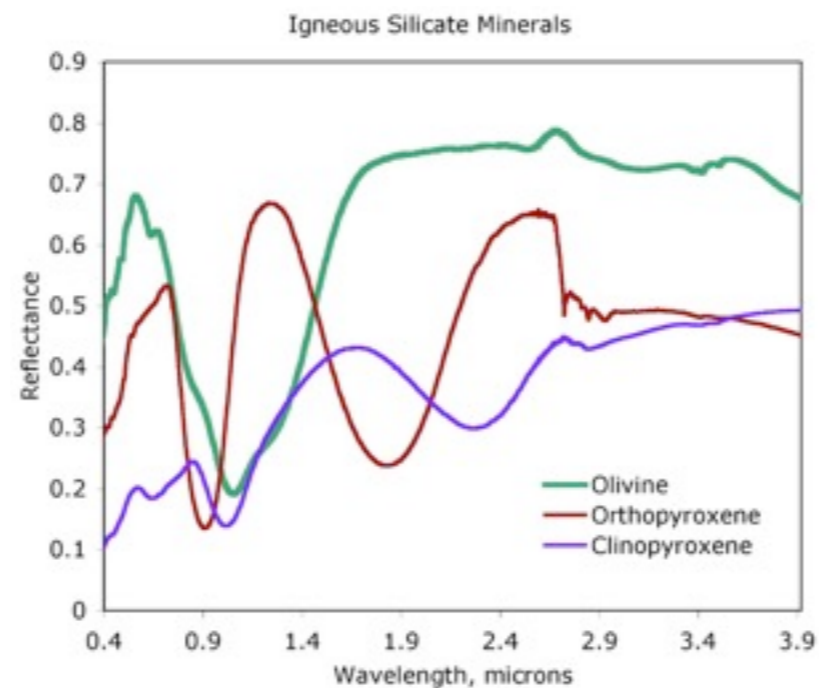
Granular material



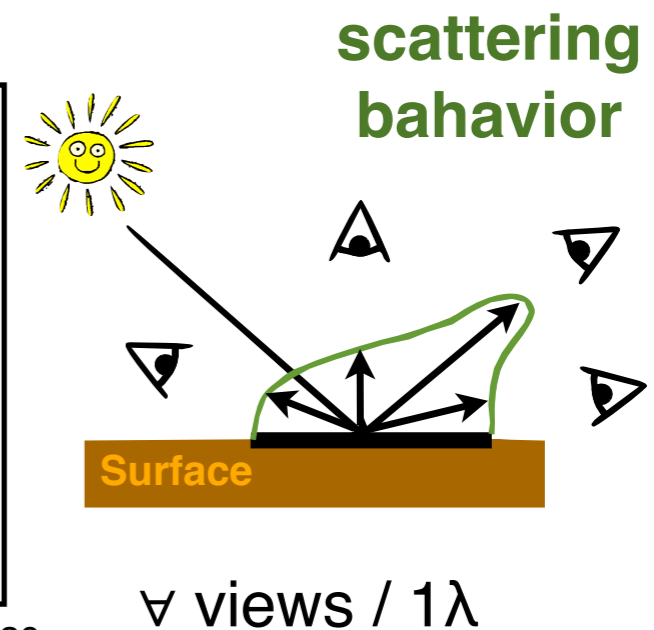
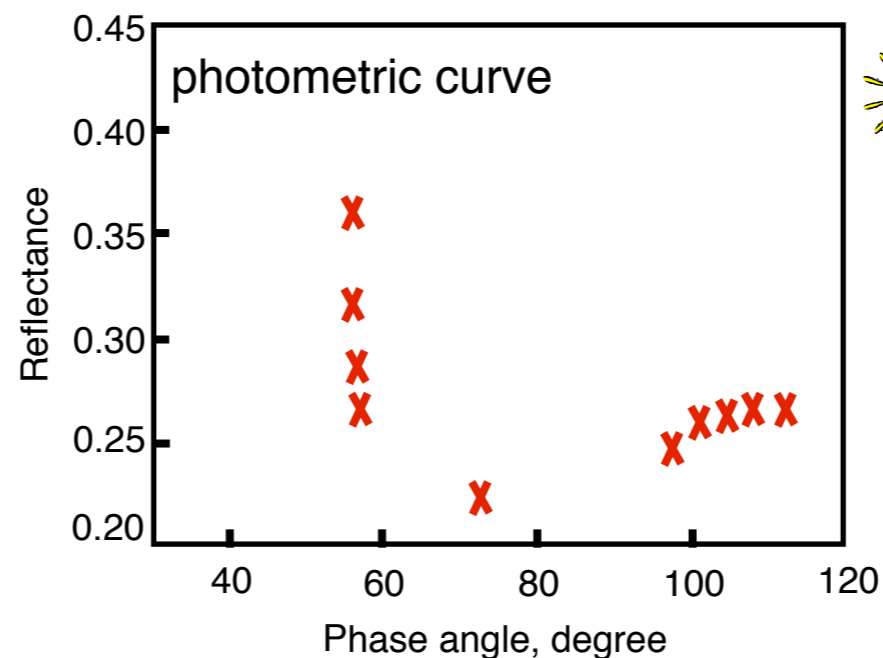
- Multiples interactions: absorption, diffusion

Spectro-photometry

- Spectroscopy



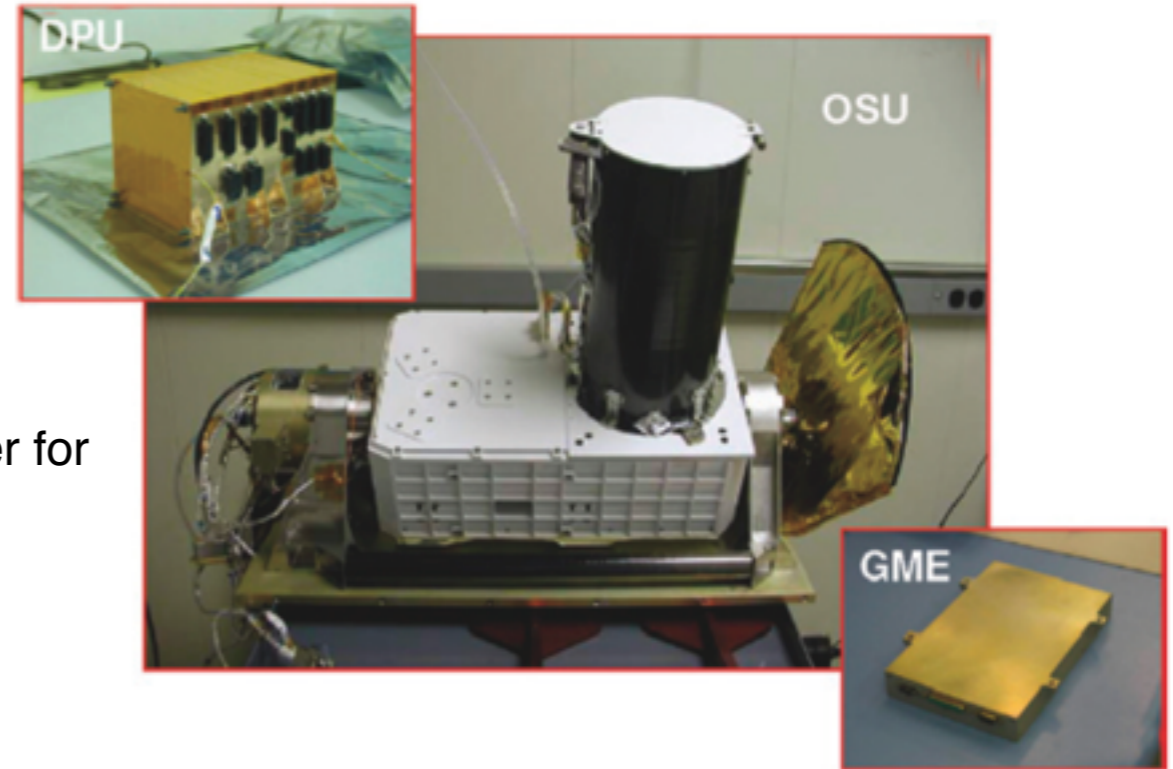
- Photometry



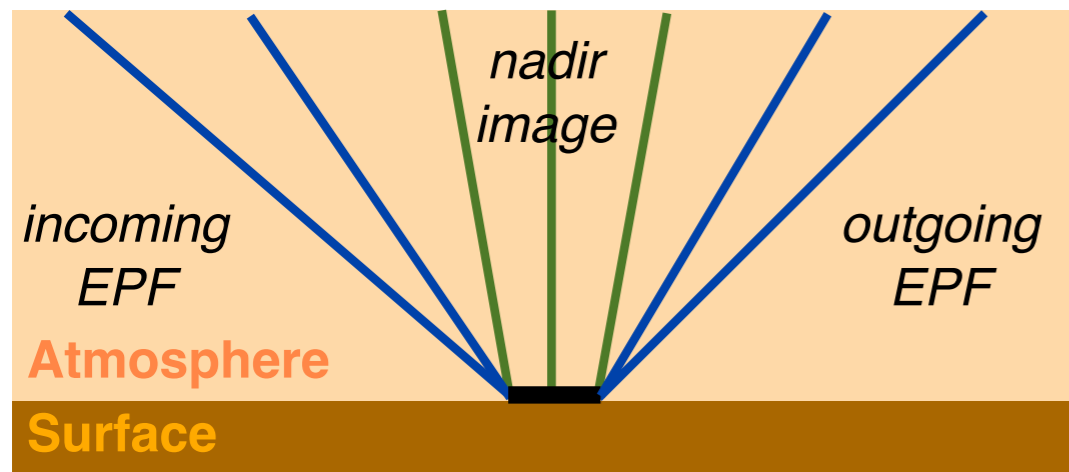
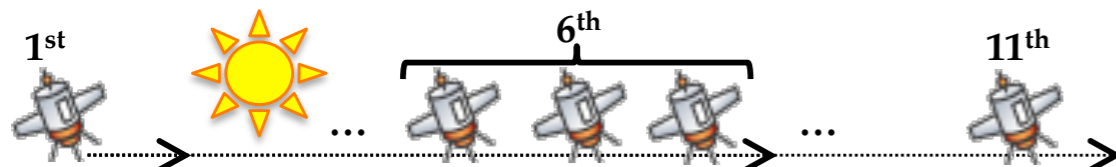
Instrument

CRISM (Compact Reconnaissance Imaging Spectrometer for Mars in Mars Reconnaissance Orbiter spacecraft)

Murchie et al., JGR, 2007

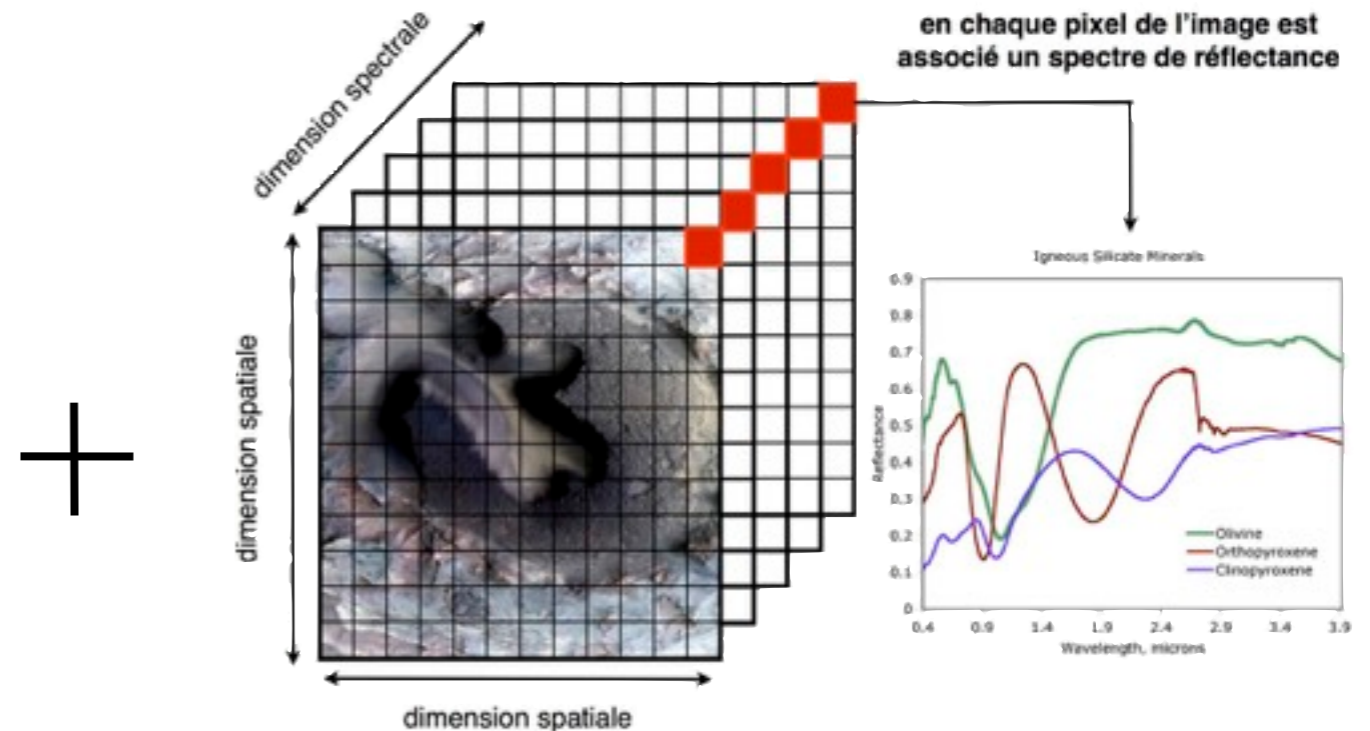


Targeted observations 11 multi-angle images



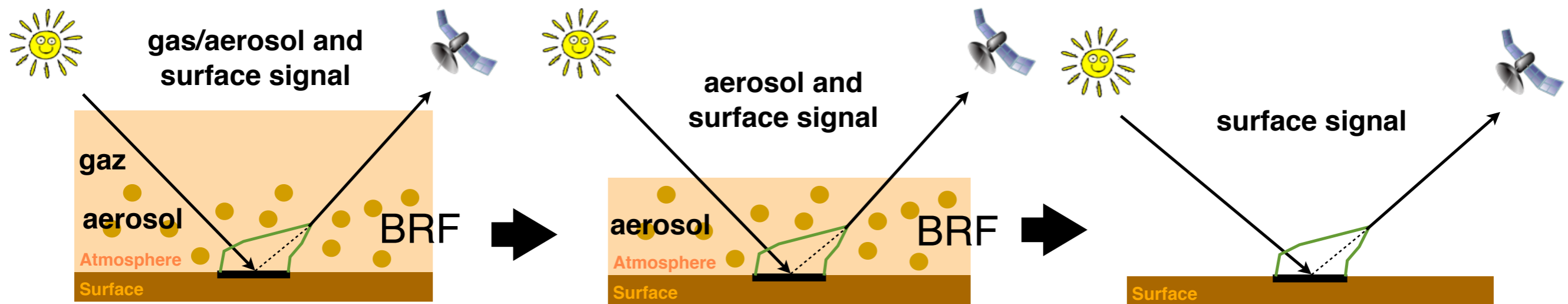
10 off-nadir images (180 m/pxl)
 $\pm 70^\circ$, constant inc
 1 nadir image (20 m/pxl)

Hyperspectral image (0.36 to 3.92 μm)



credit: <http://crism.jhuapl.edu>

Spaceborne image correction

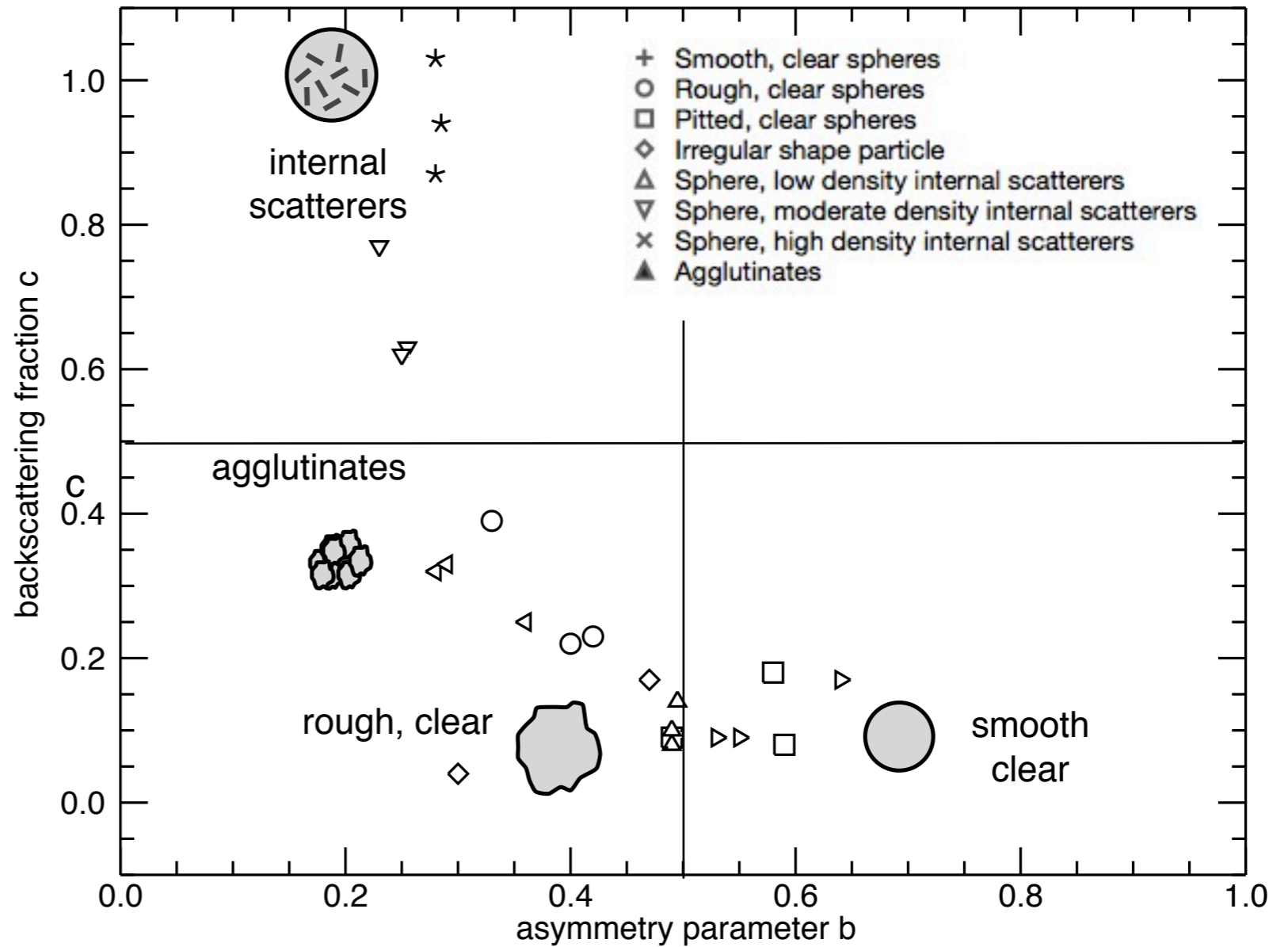
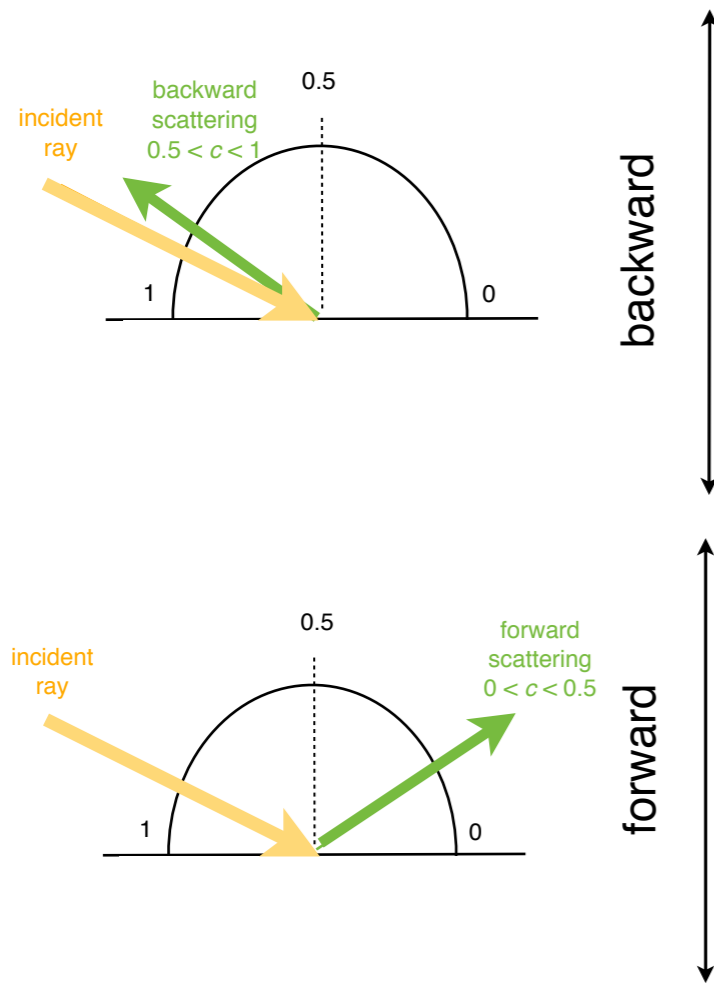


Ceamanos et al. JGR, 2013

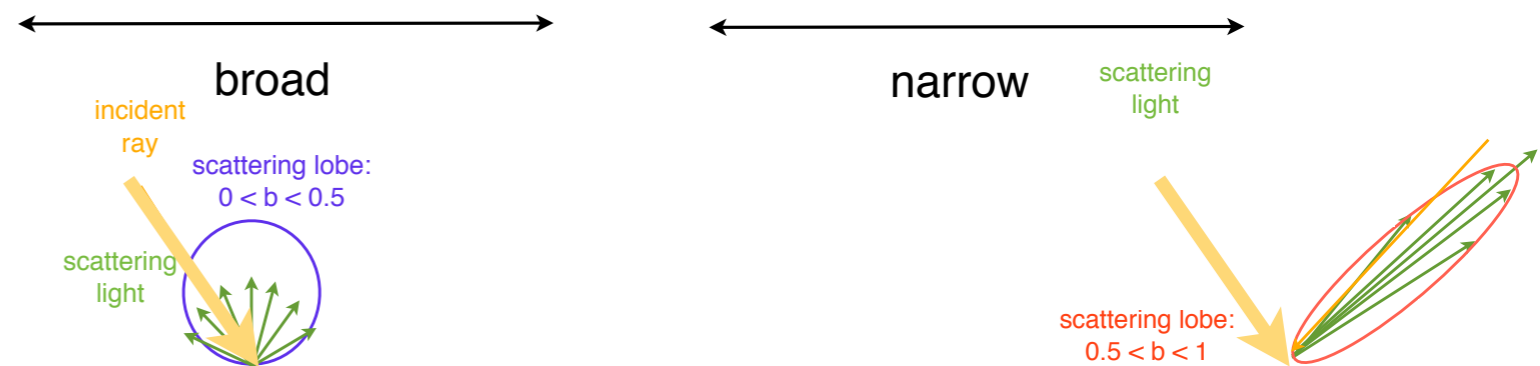
- Atmosphere contribution: aerosols + gaz

Diffusion = microtexture

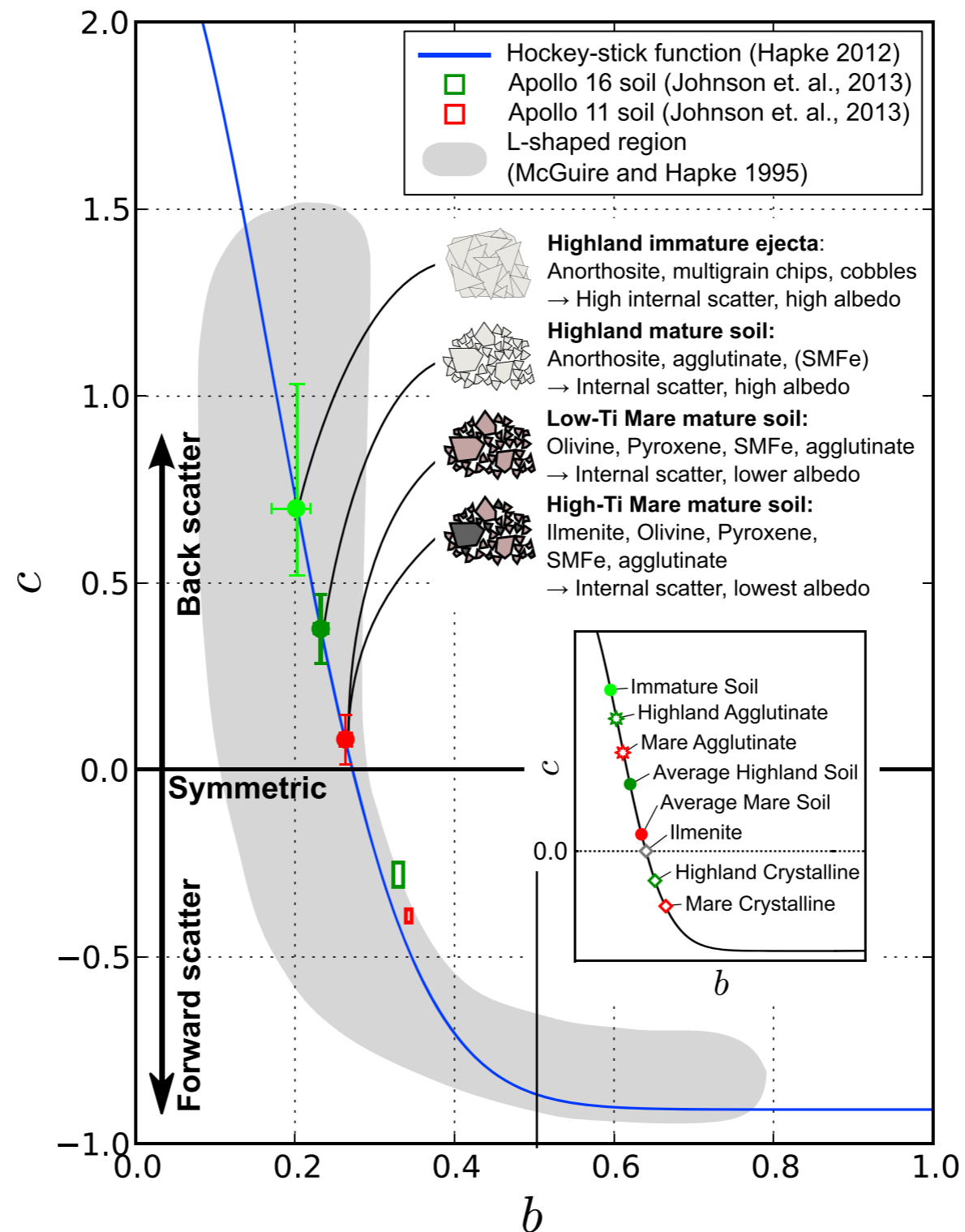
McGuire and Hapke, 1995



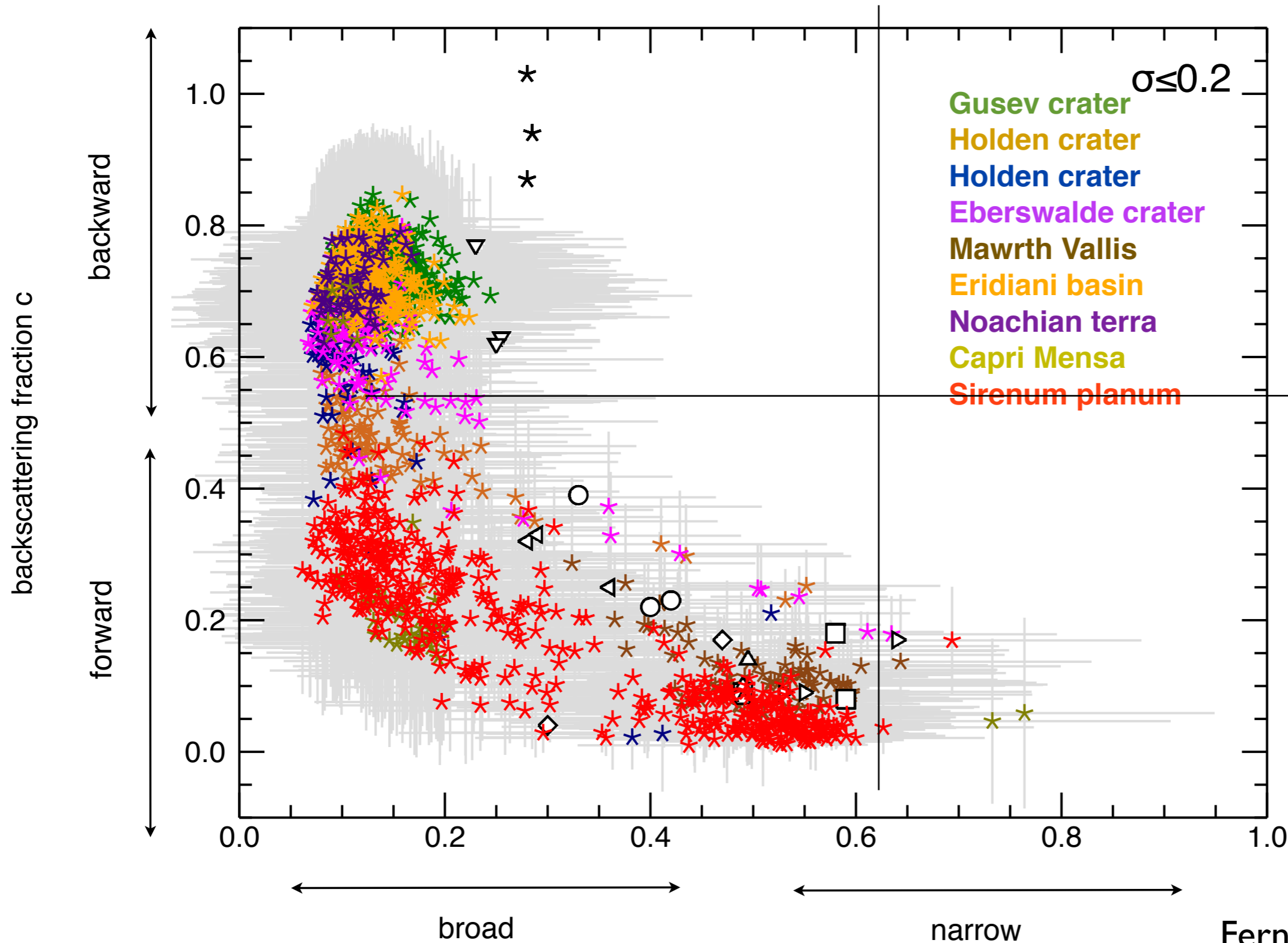
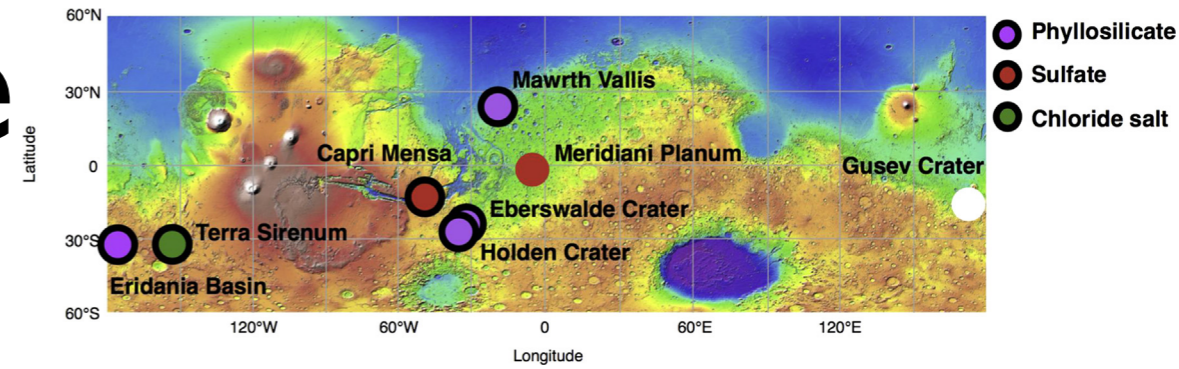
Experimental study on artificial, isolated, and centimeter particles



Microtexture on the Moon



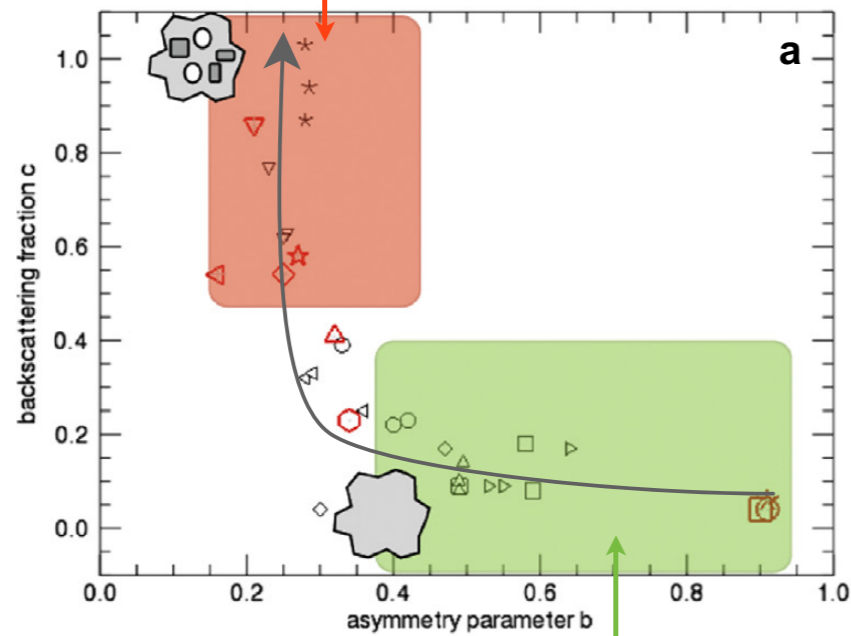
Diverse microtexture on Mars



slow cooling rate or volatile-rich magma

[Eberswalde crater, Holden crater, Eridiana Basin, Gusev crater]

Volcanic material formation
(effusive and explosive eruptions)

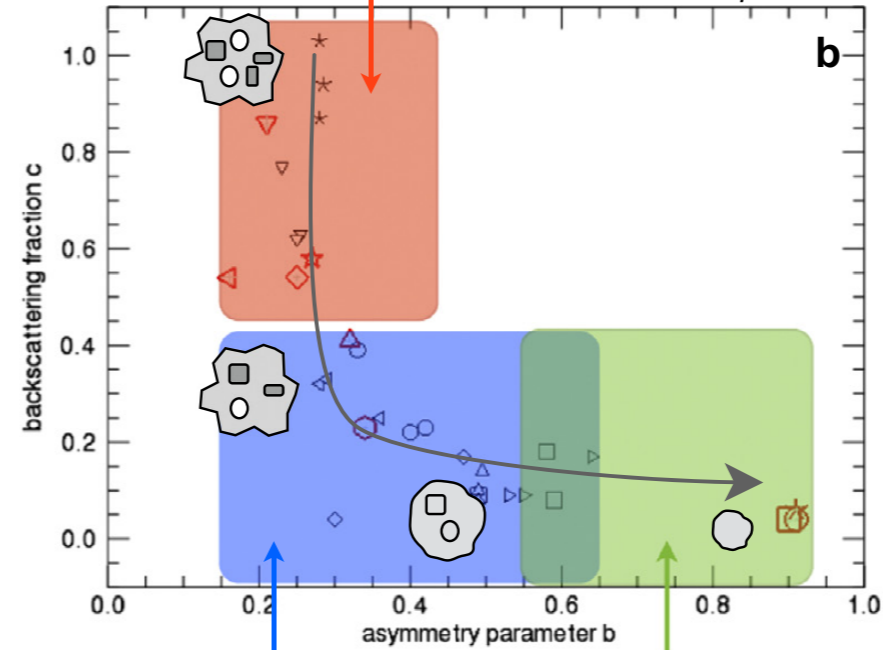


fast cooling rate or volatile-poor magma

short transportation time and/or external contribution

[Eberswalde crater, Holden crater, Eridiana Basin, Gusev crater]

Aqueous / aeolian alteration
and transportation



intermediate transportation time

[Terra Sirenum, Capri Mensa, Mawrth Vallis]

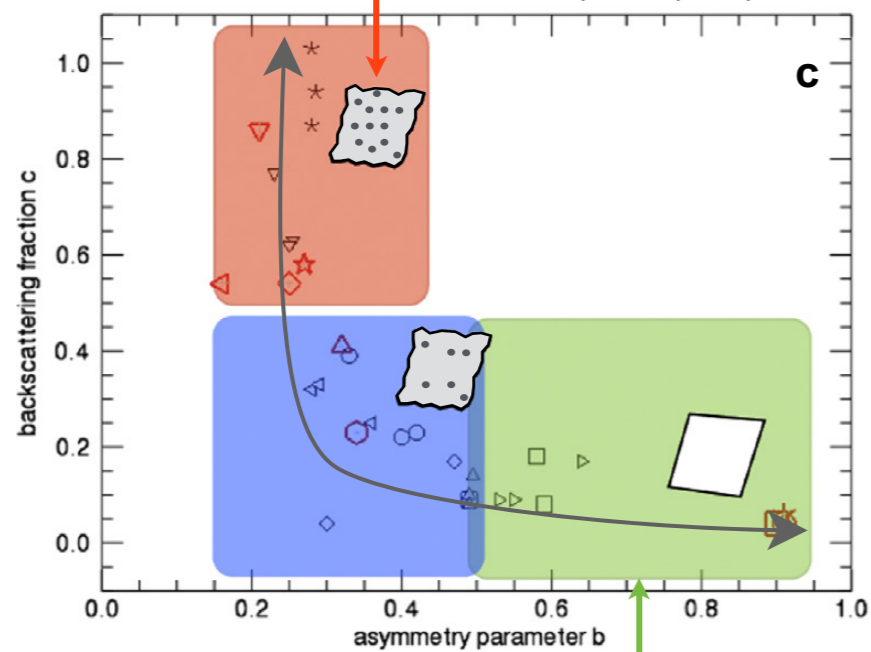
long transportation time

[Eberswalde crater, Holden crater, Mawrth Vallis]

complex history of diagenesis and/or external contamination

[Meridiani Planum]

Evaporitic precipitation



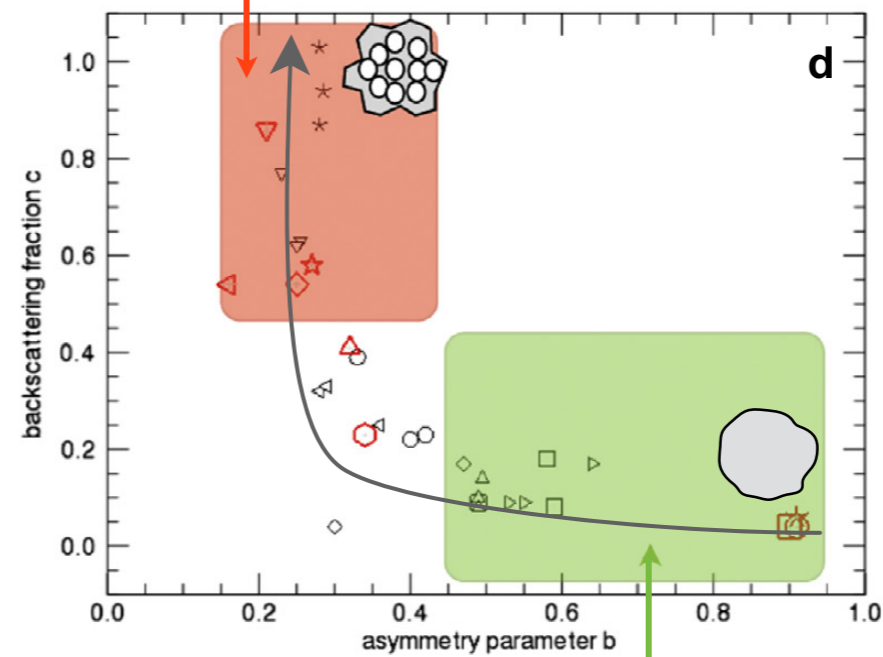
simple diagenesis

[Capri Mensa, Terra Sirenum, Meridiani Planum]

amorphized materials

[agglutinates in the Lunar regolith]

Space weathering



unaltered

[Mawrth Vallis, Eberswalde crater, Holden crater, Capri Mensa, Terra Sirenum]



Conclusion

- Image, spectroscopy, hyperspectral, multi-angular
- Quantitative geomorphology
- Composition to microtexture

- Surface processes?
- History of the planetary surface?



Parcours Planétologie Ile de France

Master Planétologie

<http://planeto.geol.u-psud.fr/master>



Merci !