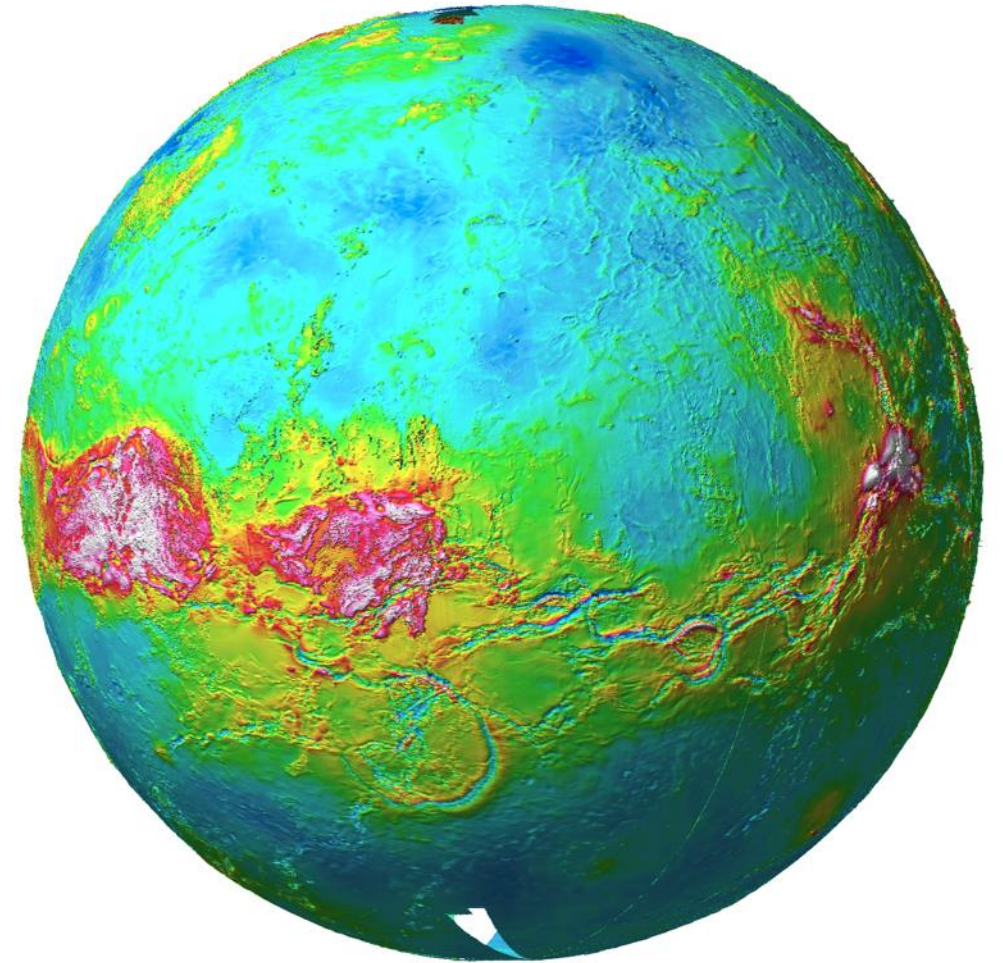


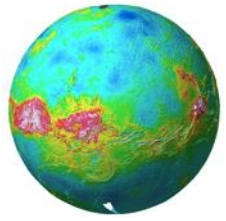
Surface and Interior (Comparative Planetology) Geodynamics & Habitability

Sue Smrekar

JPL Jet Propulsion Laboratory
California Institute of Technology

**Decadal Survey 2023 Venus
Panel
April 21, 2021**





Recommendations

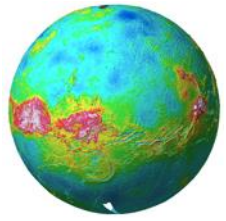
Address fundamental open science questions for rocky planet evolution and habitability:

- Volcanic history: catastrophic or no? influences all data interpretation
- What process are active? provides a window into the interior
- Tectonic/geodynamic system (today? In the past?) critical for evolution
- Why no dynamo? Critical for thermal/chemical evolution
- Volatile history (see also talks on tesserae, noble gasses, etc.)

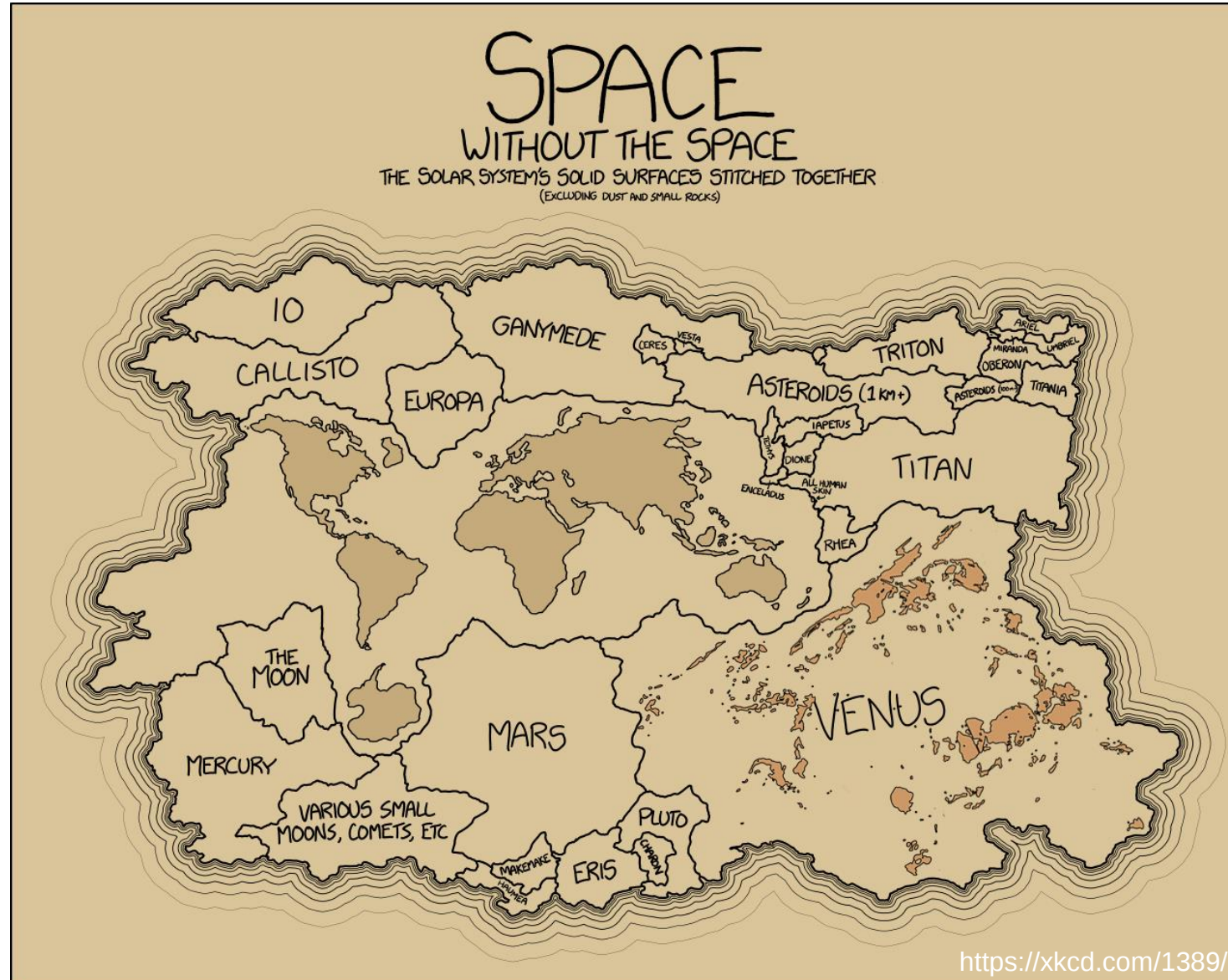
Measurements needed:

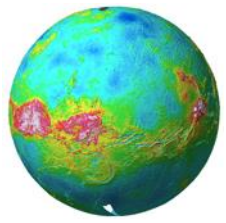
- Orbital
 - Topography, SAR imaging, NIR spectroscopy, Gravity
- Landed (and/or Aerial platforms)
 - Geochem: Elemental composition (Major, minor, trace (?)) and Mineralogy
 - Geophys: Seismology, Heat flow, Electromagnetic sounding, Magnetometry, Gravimetry

Venus exploration would benefit greatly from a logical sequence of missions.

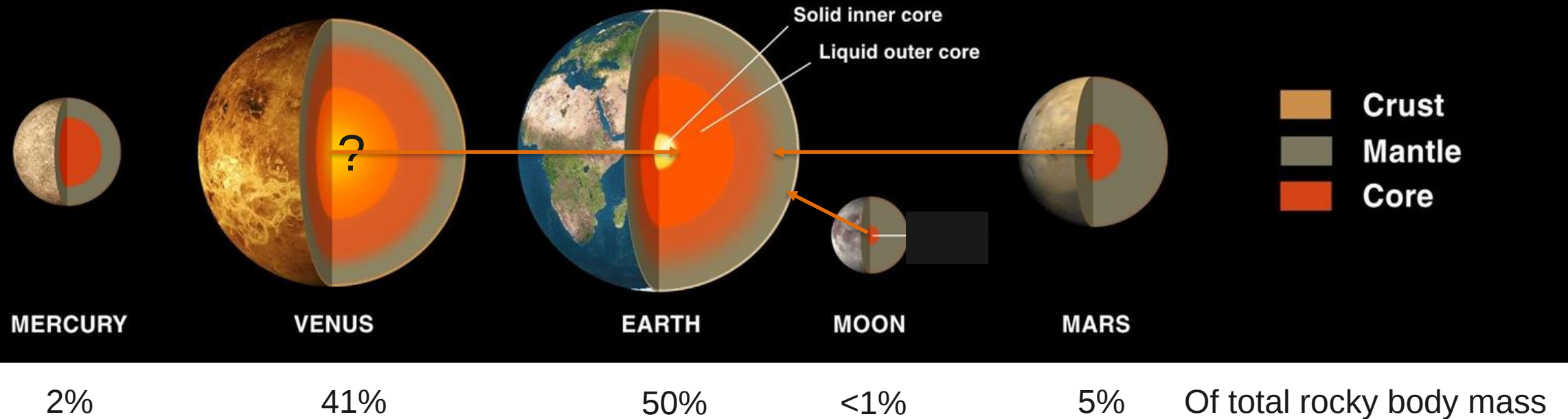


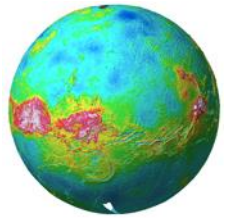
Venus represents 41 % of mass of rocky planets...





Only Venus and Earth share similar P,T states

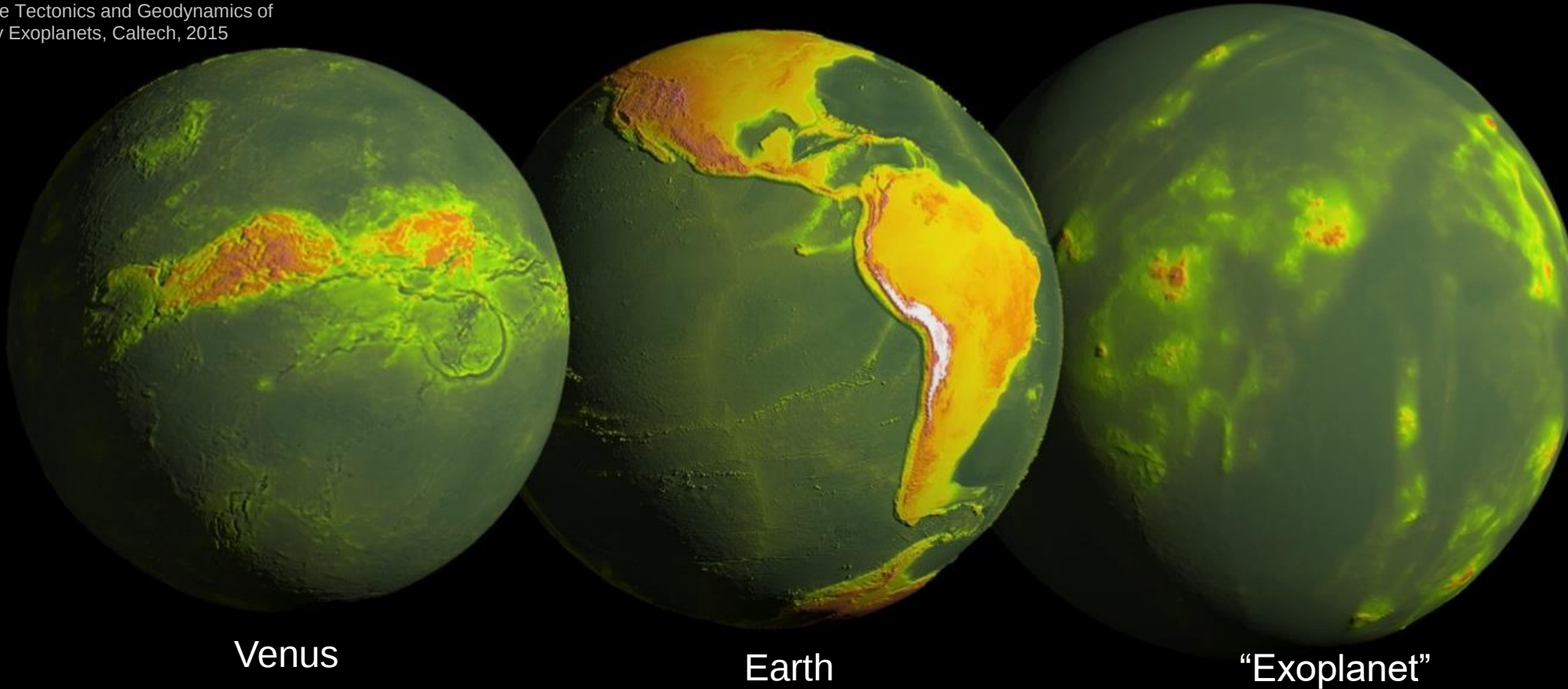




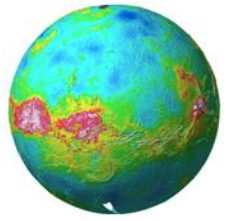
Venus as an Archean analog



Conference: Comparative Tectonics and Geodynamics of
Venus, Earth, and Rocky Exoplanets, Caltech, 2015



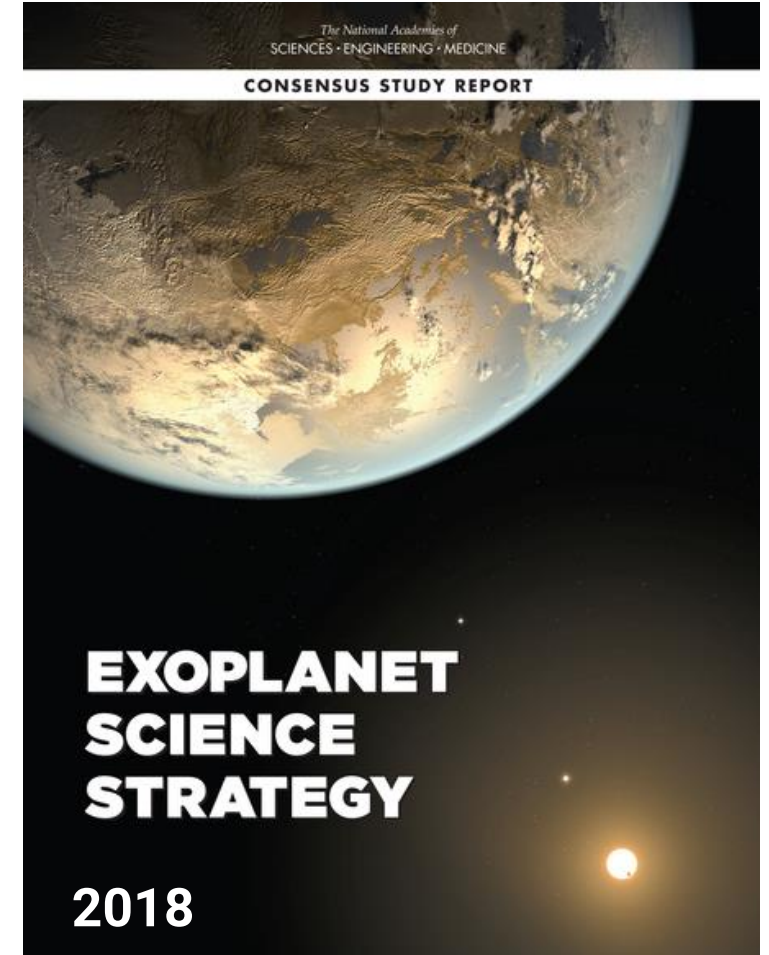
Venus has similar interior pressure, high surface and lithospheric T (due to its greenhouse). Subduction and continents may occur on Venus and elucidate their formation on Early Earth.



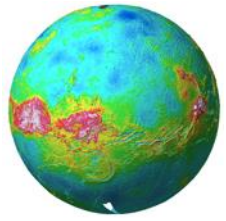
How to find a habitable exoplanet..

Factors expected to impact habitability:

- Oceans on the planetary surface
- Secondary atmosphere
- Tectonic/volcanic activity, weathering processes
- Internal energy budget
- Magnetic field
- Feedback between processes



Geodynamic evolution a key question for discovering Earth 2.0



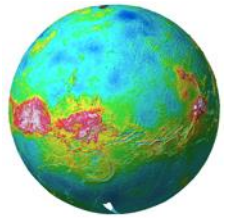
How to find a habitable exoplanet..

Factors expected to impact habitability:

- (Past) Oceans on the planetary surface (**Tesserae!**)
- Secondary atmosphere (**Volcanic history, water outgassing**)
- Tectonic/volcanic activity & weathering processes (**Volcanism, deformation, weathering**)
- Internal energy budget (**Heat flow estimates- gravity & topo**)
- (Likely past) Magnetic field (**Core size, mantle viscosity**)
- Feedback between processes

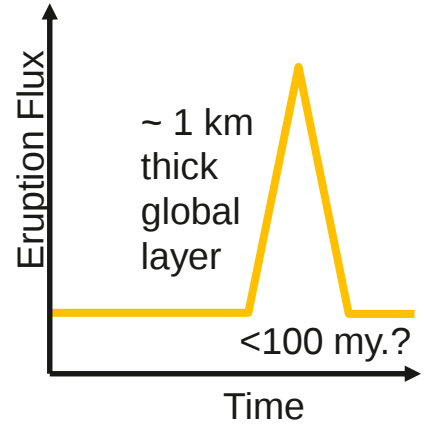


Only Venus is likely to be active today... and thus provides a control case for Earth



Venus 'resurfaced' 500 m.y. ago?

Mechanism 1: Volcanic resurfacing



Mechanism 2: Global foundering/overturn of lithosphere

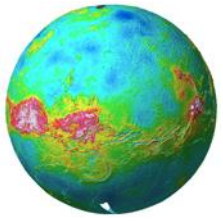
Cool idea!

Produces massive climate change!

Weird geodynamics: episodic plate tectonics

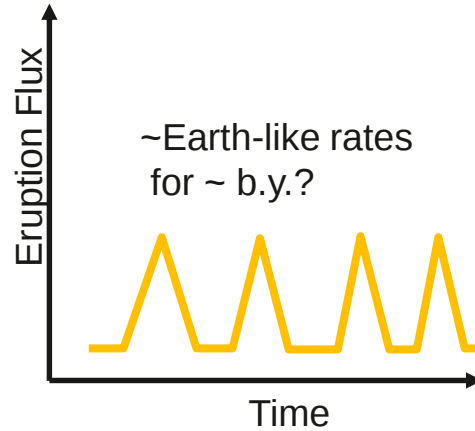
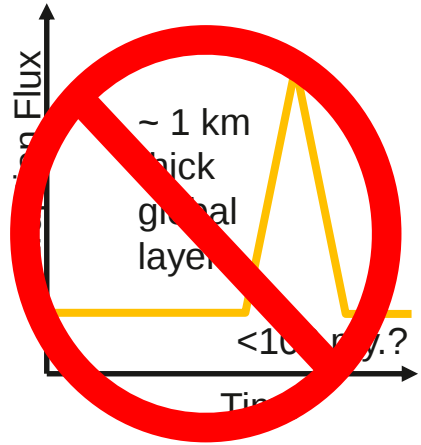
Pervades Venus science

Persistent paradigm: Venus resurfaced 500 m.a. and is geologically dead today



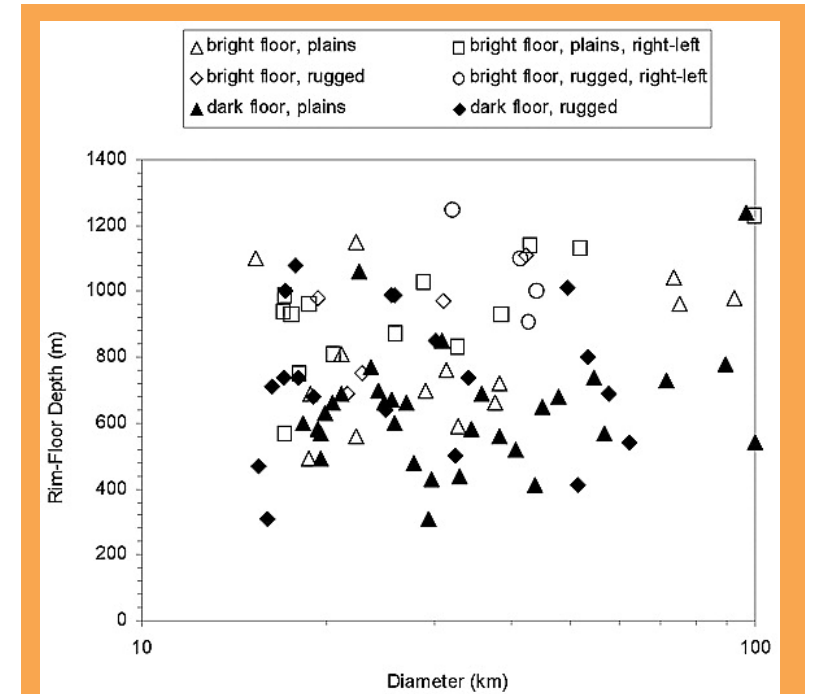
Venus 'resurfaced' 500 m.y. ago? NO!

Mechanism 1: Volcanic resurfacing



Persistent volcanism in small patches fits geologic data (extended ejecta, volcano distribution) better

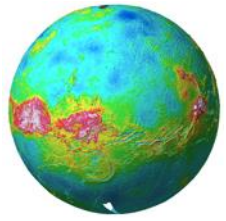
New understanding requires global high resolution & precision topography, high resolution SAR imaging



80% of craters have dark floors-
Are they volcanically flooded?
Stereo topo suggests they are shallower, and thus infilled.

Herrick and Rumpf, 2011

Incorrect paradigm inhibits new theories



How do we detect activity on Venus?

VOLCANOS:



ACTIVE VOLCANISM

Iceland 2021

RECENT VOLCANISM

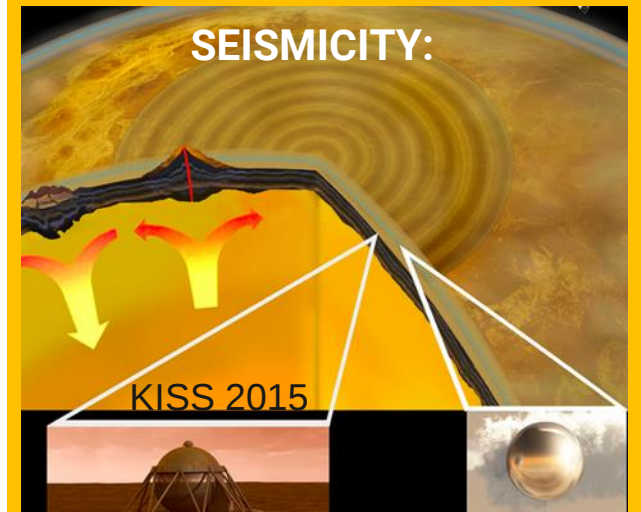
VEX VIRTIS data: Idunn Mons

Requires high SNR
NIR imaging with
multiple observations
within days

Requires high SNR
NIR imaging

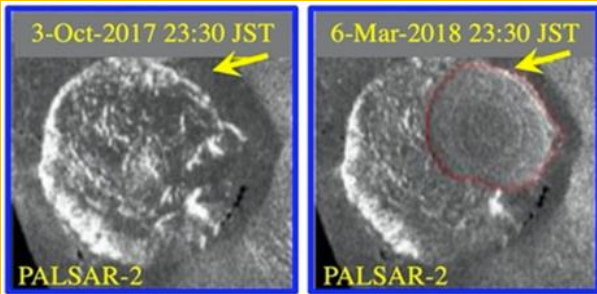


SEISMICITY:



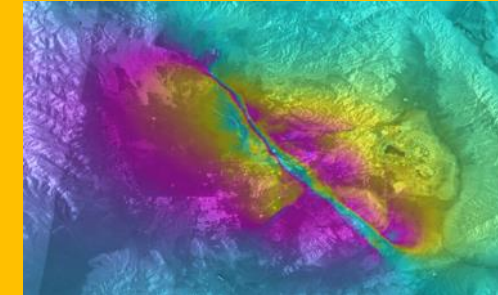
Requires: orbital/aerial
observations of waves or
extend duration lander

RADAR CHANGE DETECTION:



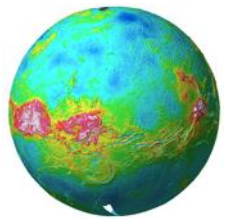
Requires a difference in
dielectric properties
(change in surface
roughness) between
subsequent radar images

ACTIVE FAULTING OR VOLCANIC DEFORMATION:

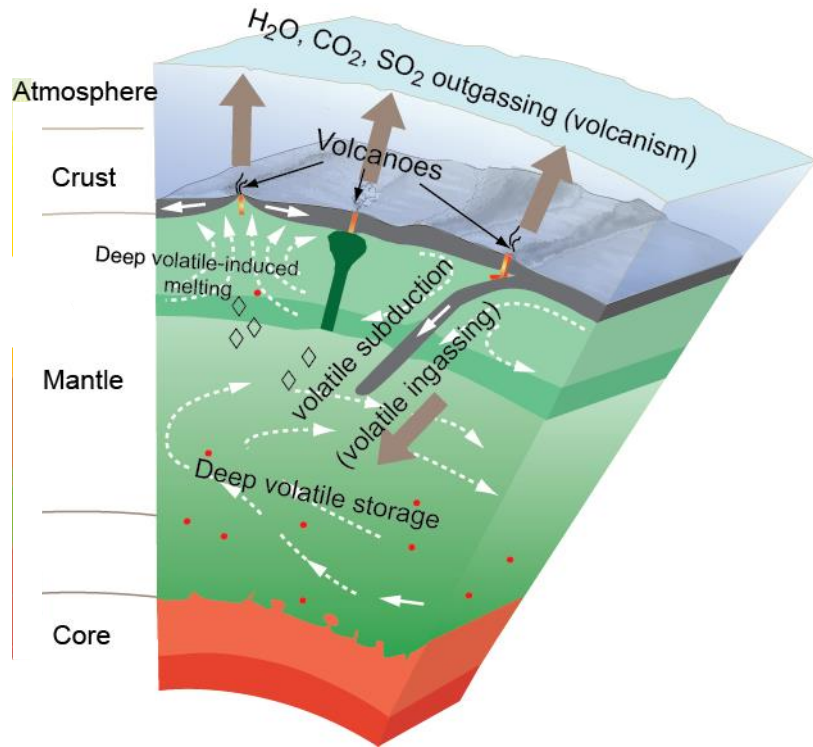


Requires
InSAR,
precision
navigation,
large downlink

Habitability: Activity provides chemical disequilibria for life.

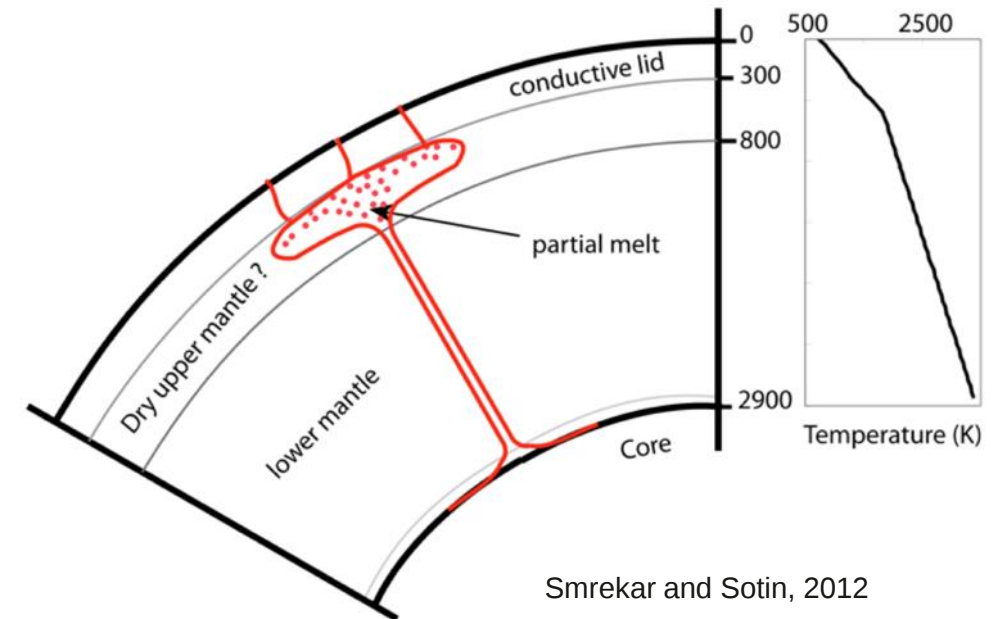


Volcanism/tectonism link surface, atmosphere, and interior



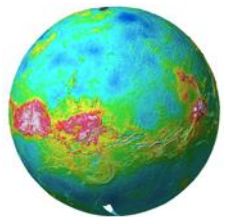
<http://dasgupta.rice.edu/>

- Venus example:
 - Does all recent volcanism due to pressure release melting come from deep mantle plumes?
 - Is lower mantle water (or other volatiles) needed to enable melting? Is the upper mantle desiccated?



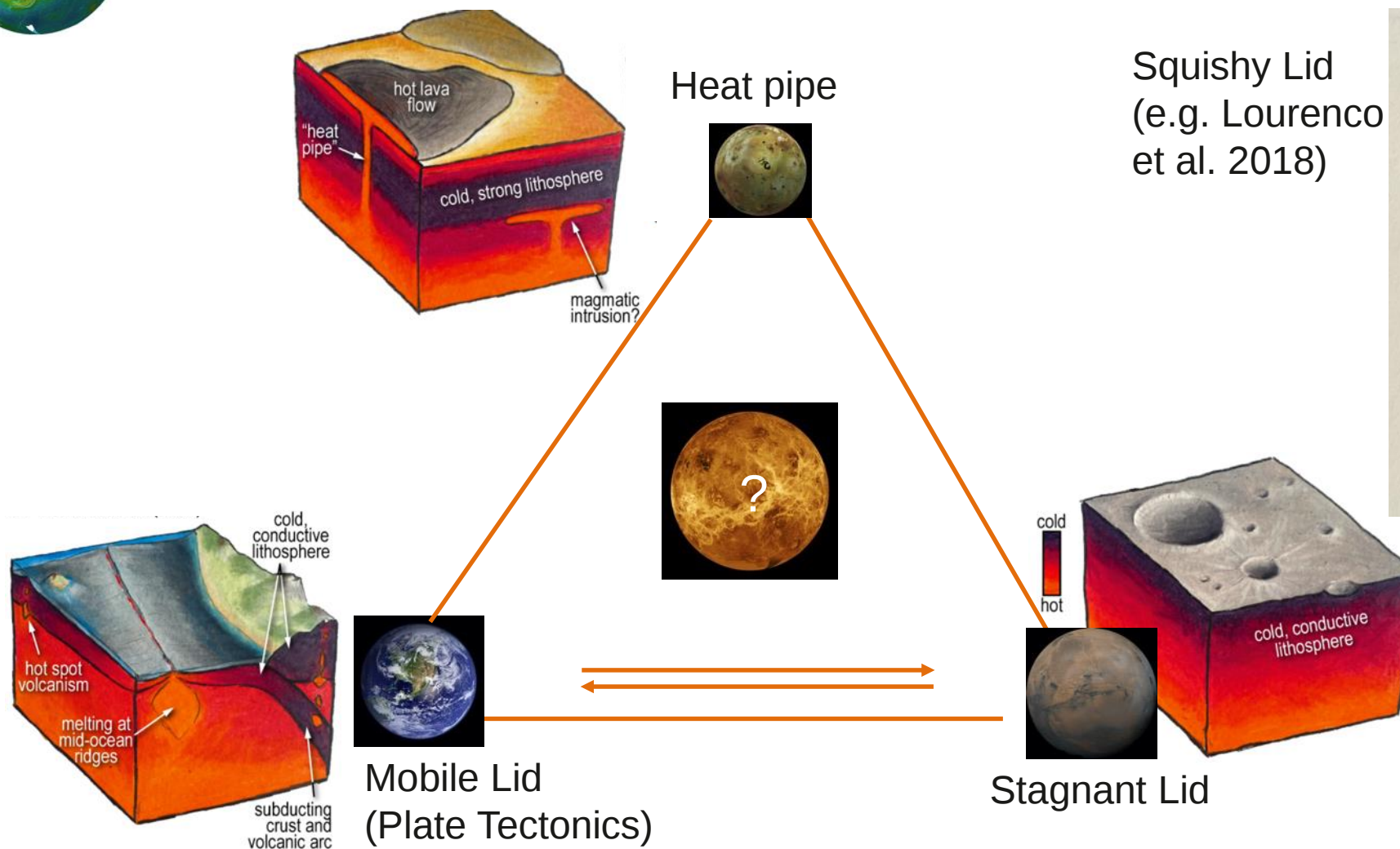
Smrekar and Sotin, 2012

Determining what processes are active today provides constraints on thermal and volatile evolution

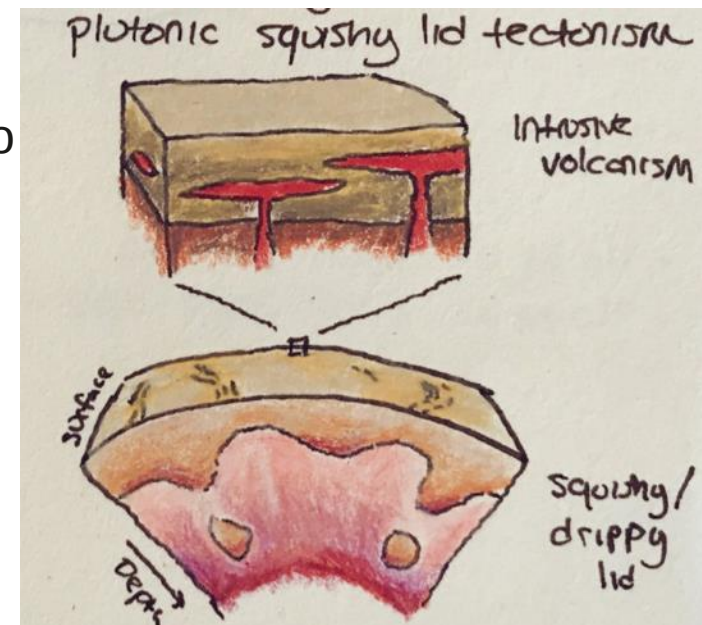


What is Venus' current geodynamic state?

Cartoons: James Tuttle Keane, Io, Decadal Survey White Paper 2020



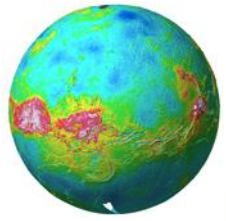
Squishy Lid
(e.g. Lourenco
et al. 2018)



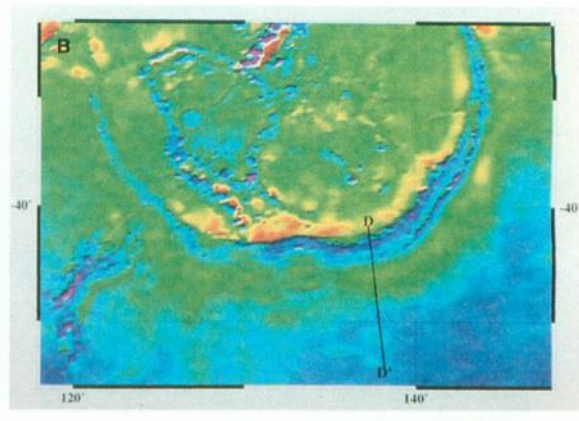
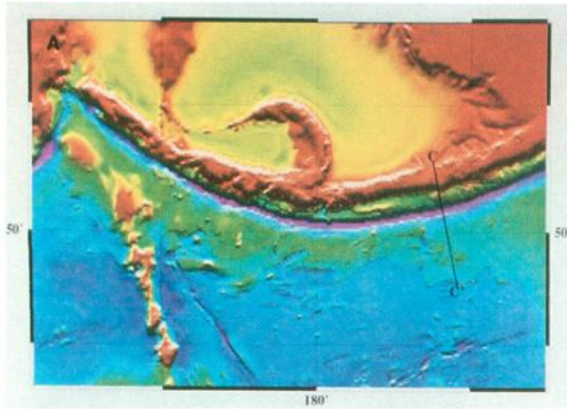
Venus likely has an
entirely different
mechanism!

Habitability: Does Venus represent an entirely different geodynamic regime?

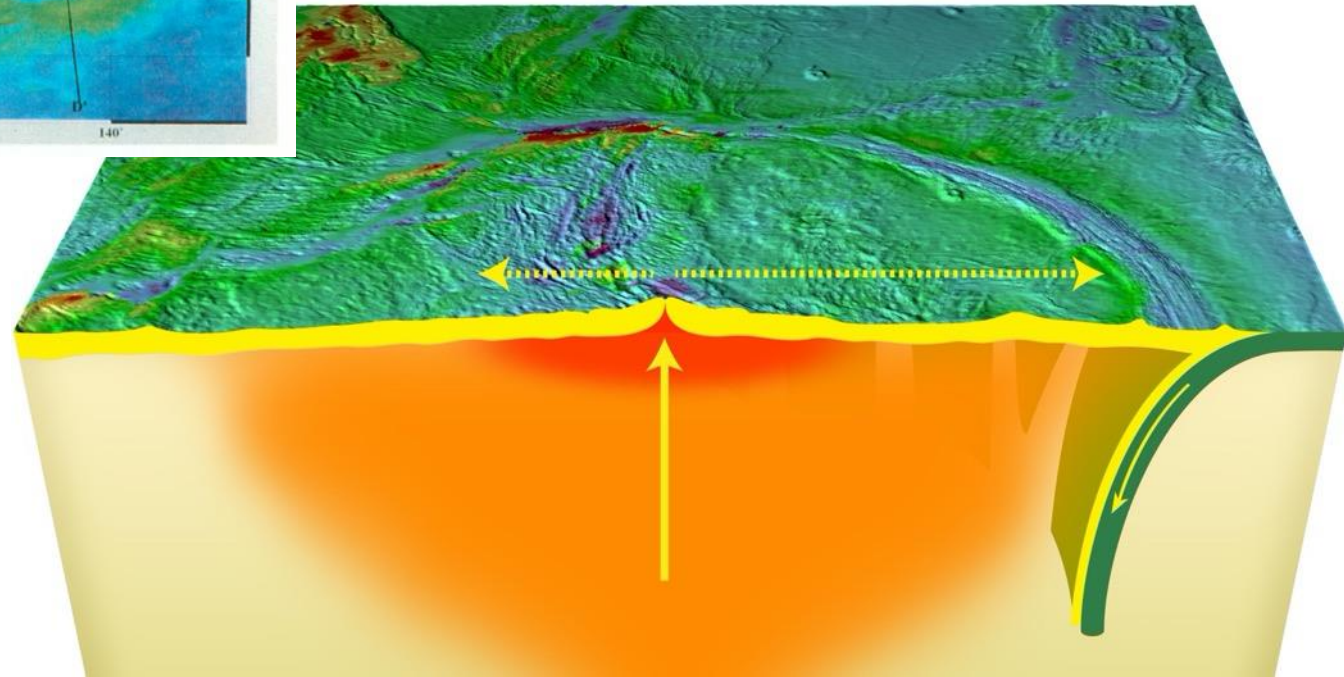
Evolution: Is Venus losing heat & creating tesserae terrains, coronae, etc. through this mechanism?



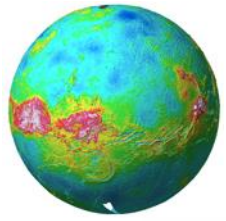
Does Venus have subduction?



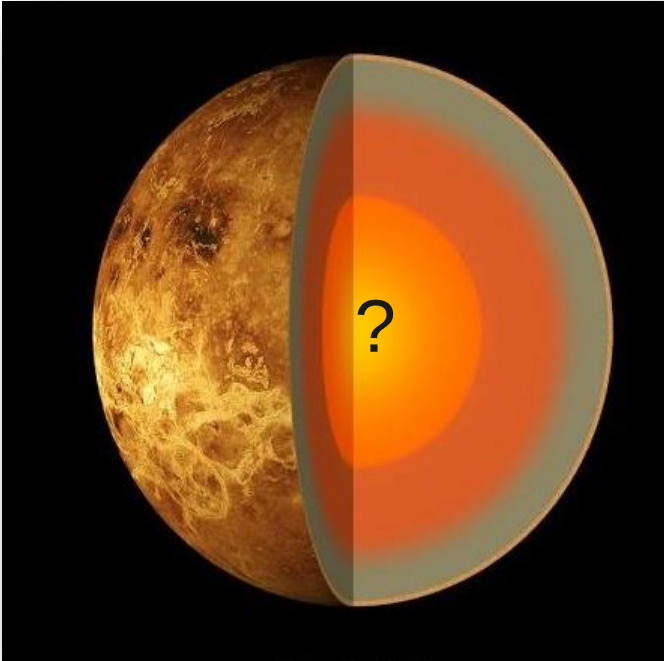
Requires high resolution
topography, SAR images,
gravity



Habitability: Subduction recycles volatiles that stabilize long term climate..
Is this how plate tectonics started on Earth?



What is the size and state of the core?



Constraints on core size & state (and thus composition) and mantle viscosity requires:
High precision Moment of Inertia, Love # & phase lag derived from a high resolution gravity field
(e.g. Dumoulin et al. 2017)

Why doesn't Venus have a dynamo??

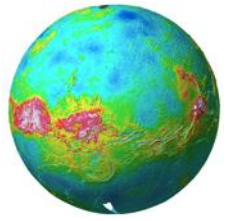
What is the structure and viscosity of the mantle?



Margot et al. 2021: core size to ± 300 km
Searching for remanent crustal magnetization/a weak dynamo requires:
magnetometry from low altitude

Habitability: Dynamos shield the surface from radiation.

What is the core heat flux contribution to thermal evolution? Why are there plumes but no dynamo?



Venus is the missing link in comparative planetology

Earth

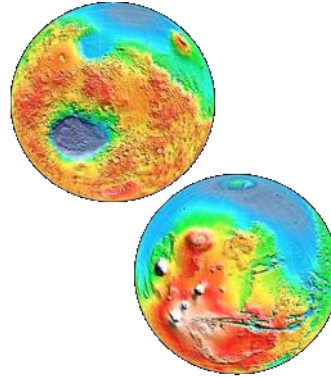
SRTM Topography



Vertical Accuracy: 6 m
Spatial Resolution: 50 m

Mars

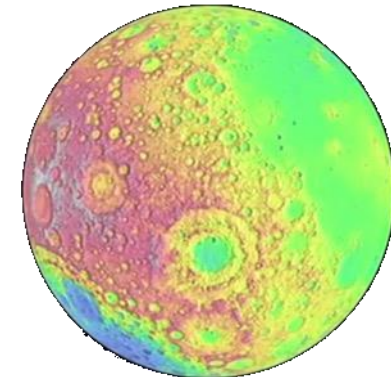
MOLA Topography



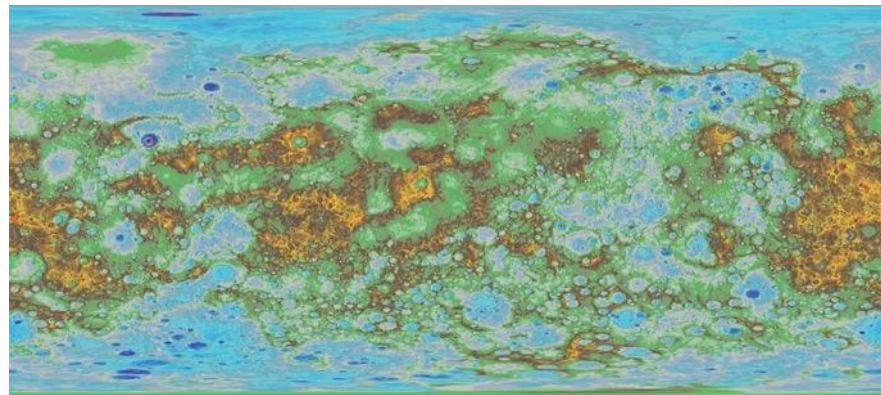
Vertical Accuracy: 3 m
Spatial Resolution: 1-2 km

Moon

LOLA Topography



Vertical Accuracy: 1 m
Spatial Resolution: 1-2 km



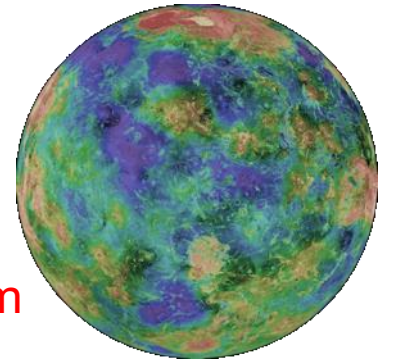
Mercury

Photoclinometry,
laser altimetry
Spatial Resolution: ≥ 2 km

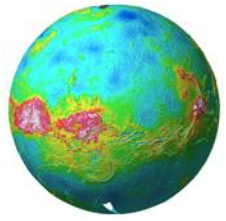
Venus

Magellan Topography

Vertical Accuracy: 80 m
Spatial Resolution: 20 km



Venus datasets are orders of magnitude lower resolution than those for other terrestrial planets



Recommendations

Address fundamental open science questions for rocky planet evolution and habitability:

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- Landed (and/or Aerial platforms)
 - Geochem: Elemental composition (Major, minor, trace (?)) and Mineralogy
 - Geophys: Seismology, Heat flow, Electromagnetic sounding, Magnetometry, Gravimetry

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Thank you!

Venus returns
as the Evening
Star on May 24

