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Corona structures key for unravelling volcano-tectonic mysteries on Venus: insights and ways forward

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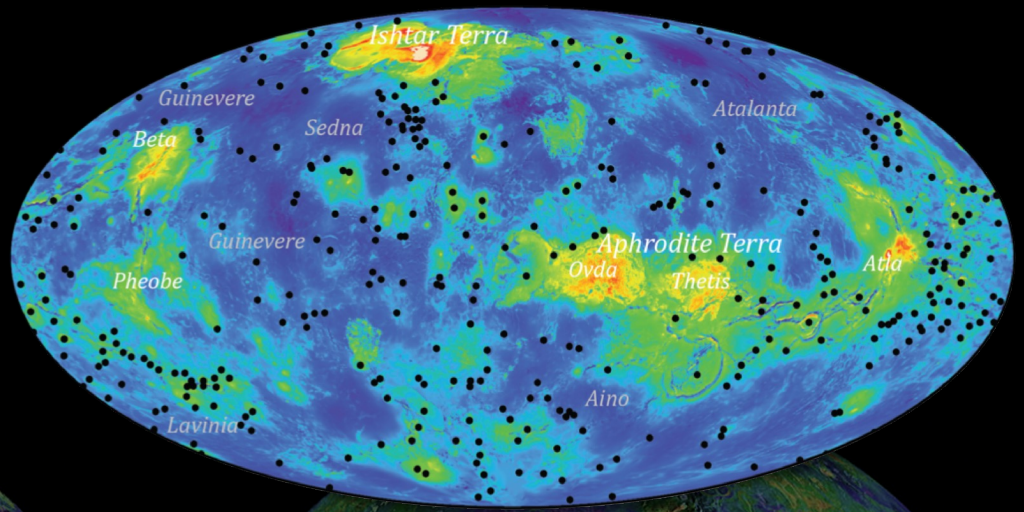
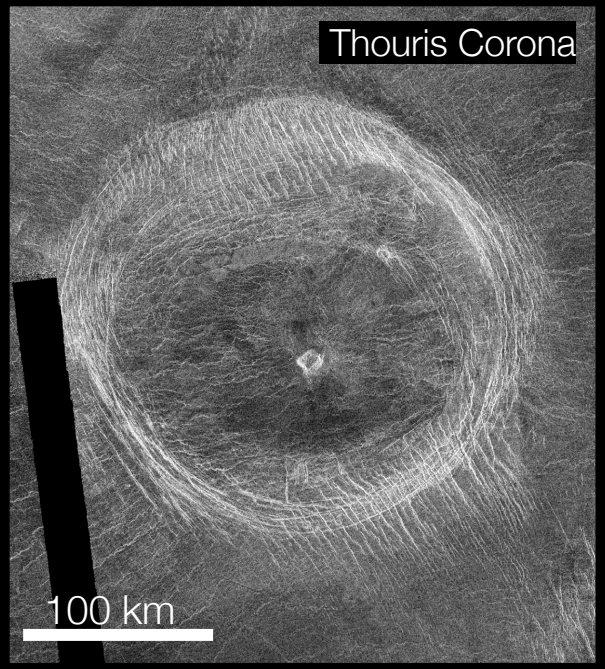
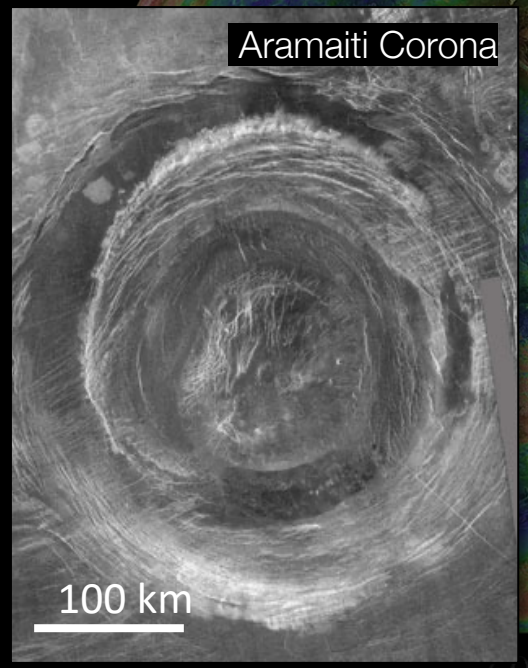
The Venusian surface

- No plate tectonics; minimal horizontal motion
- Widespread **tectonic and volcanic structures**

  e.g., **coronae**:





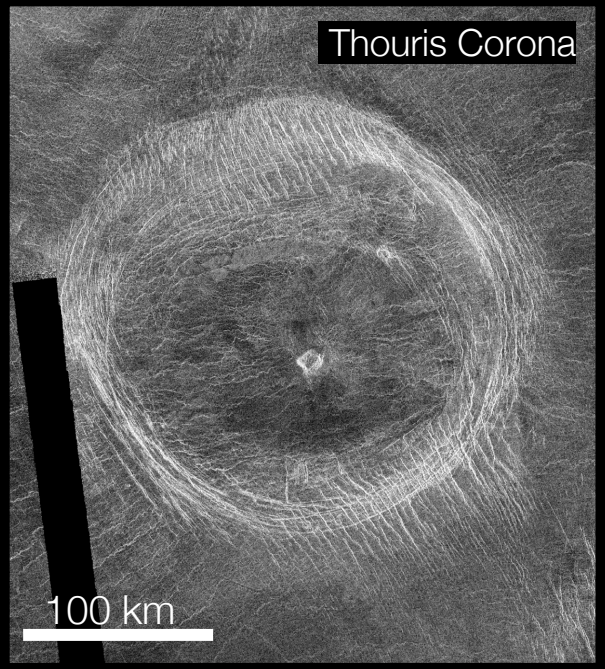


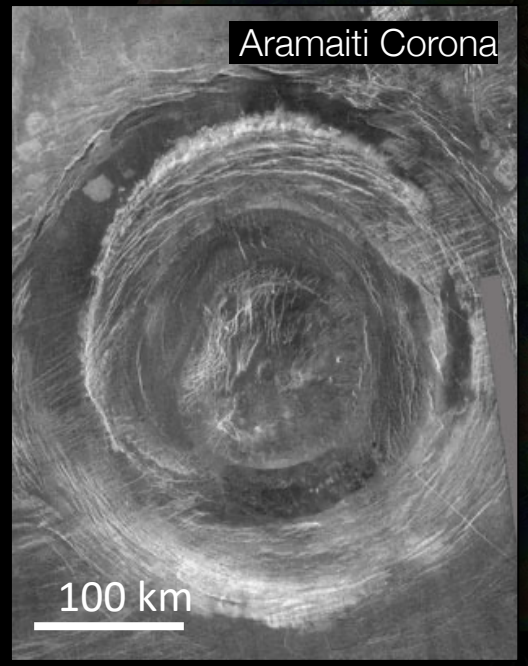
NASA/JPL/USGS

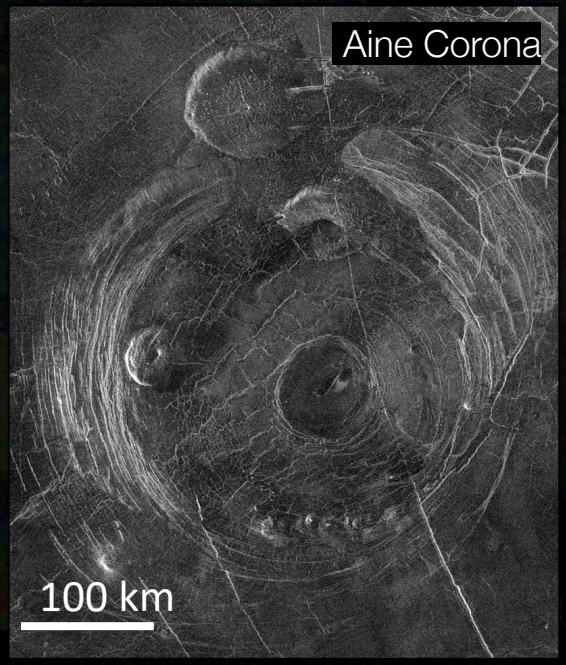
The Venusian surface

To what extend do **coronae** reflect Venus' **current interior state**?

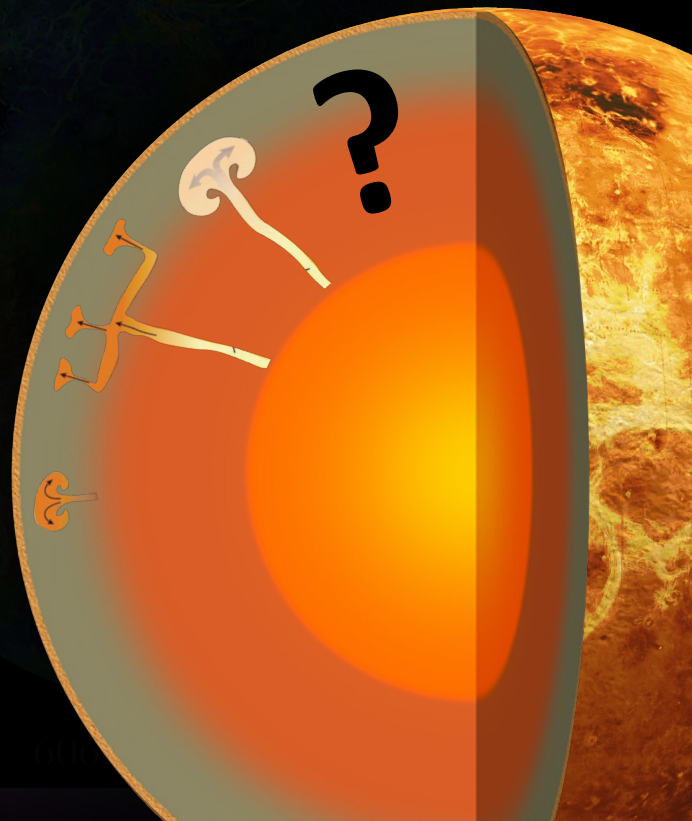
- **Apparent** young & uniform surface age (~0.5 Ga)





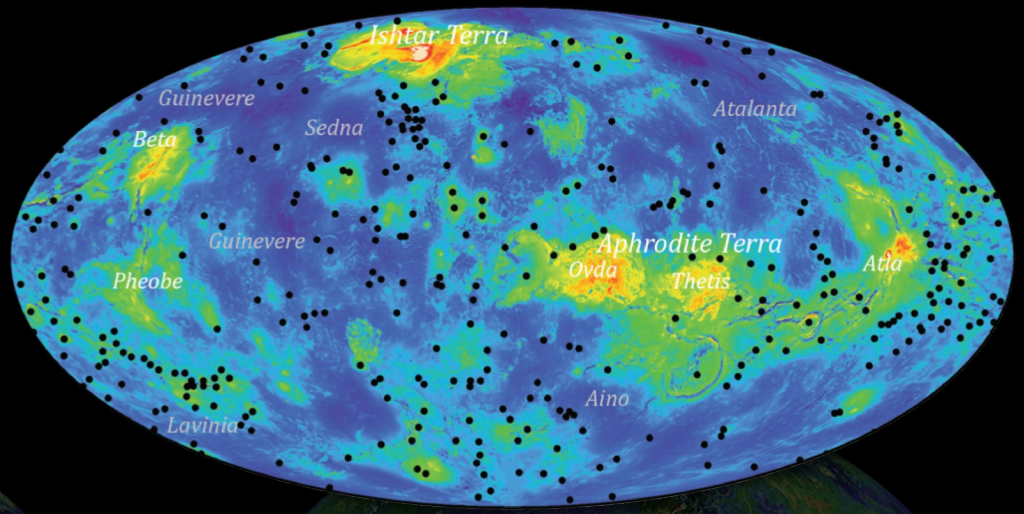


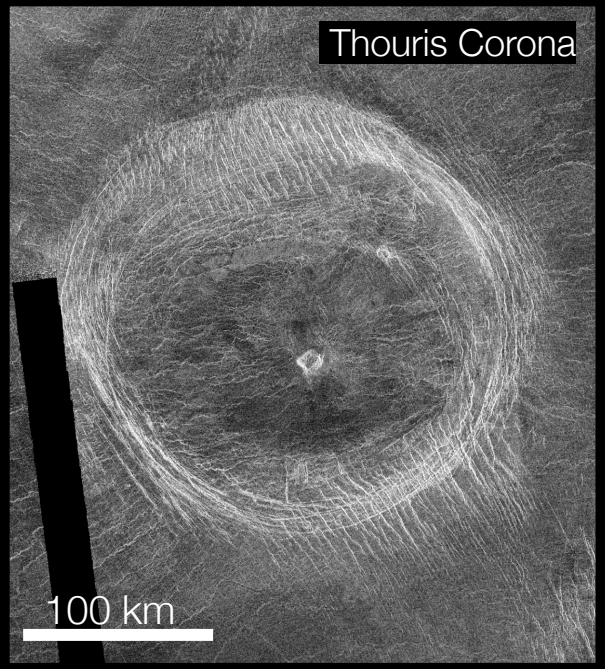
NASA/JPL/USGS

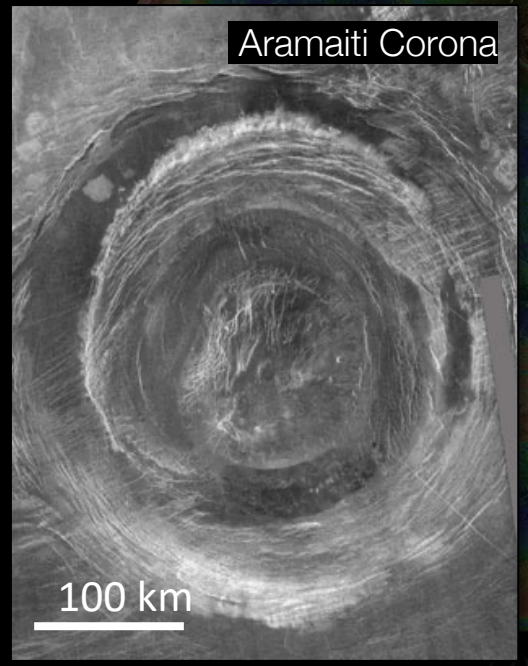


Coronae (“crowns”)

- Large ~circular **volcano-tectonic features**
- **Volcanism**, concentric fault patterns, and topography
- Various dimensions (60-1000s km) and **morphologies**





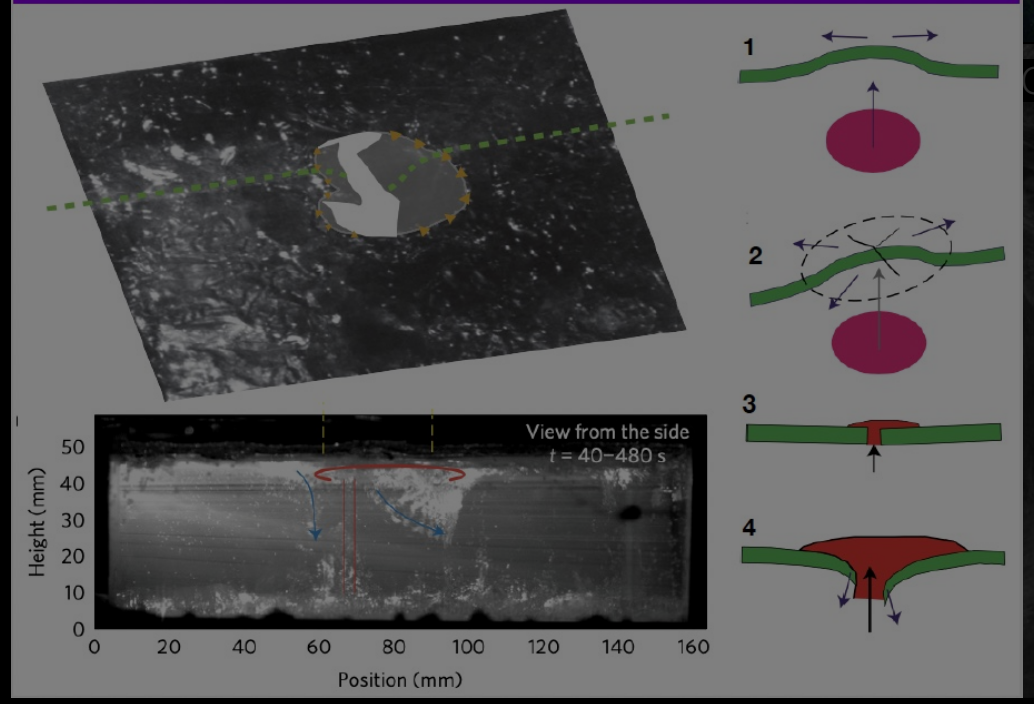


NASA/JPL/USGS

Formation of coronae

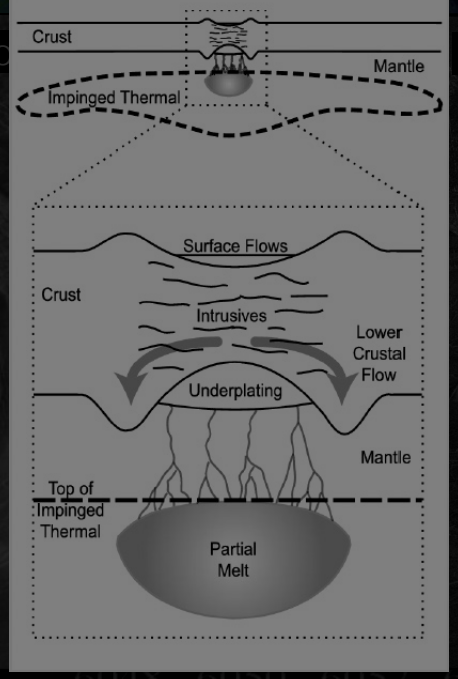
- Various hypotheses
- Most involve the interaction of (upwelling?) **mantle plumes** and the lithosphere

Plume-induced subduction



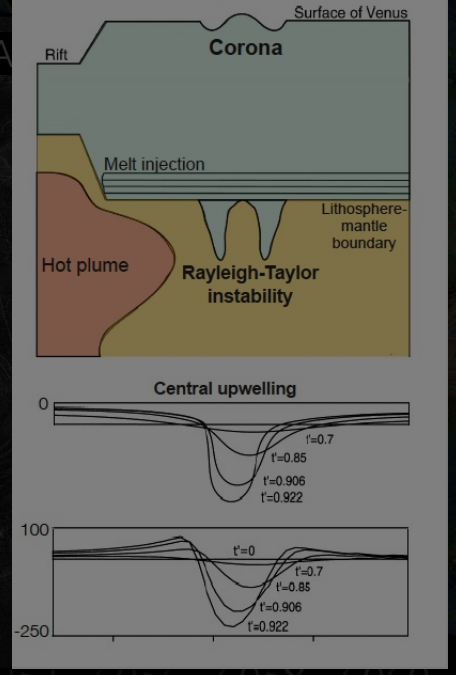
Davaille et al. (2017)

Magmatic loading



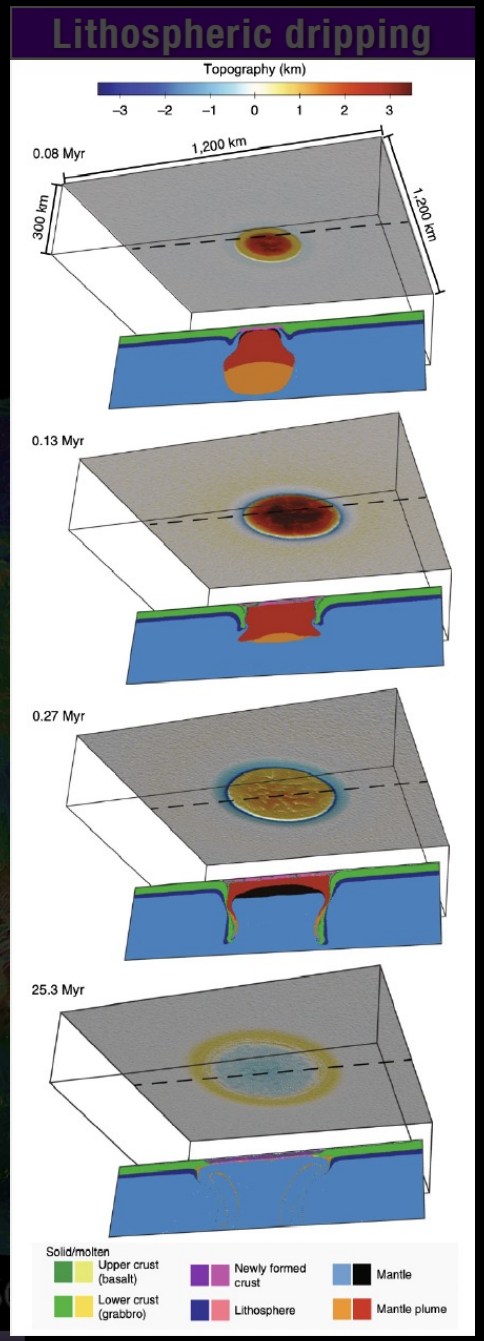
Hoogenboom & Houseman (2006); Piskorz et al. (2014)

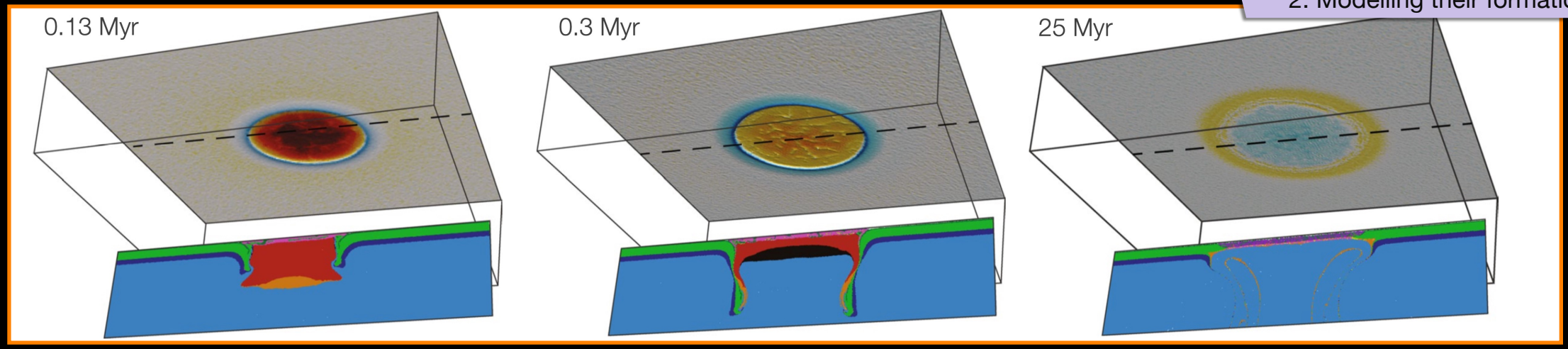
Rayleigh-Taylor instability



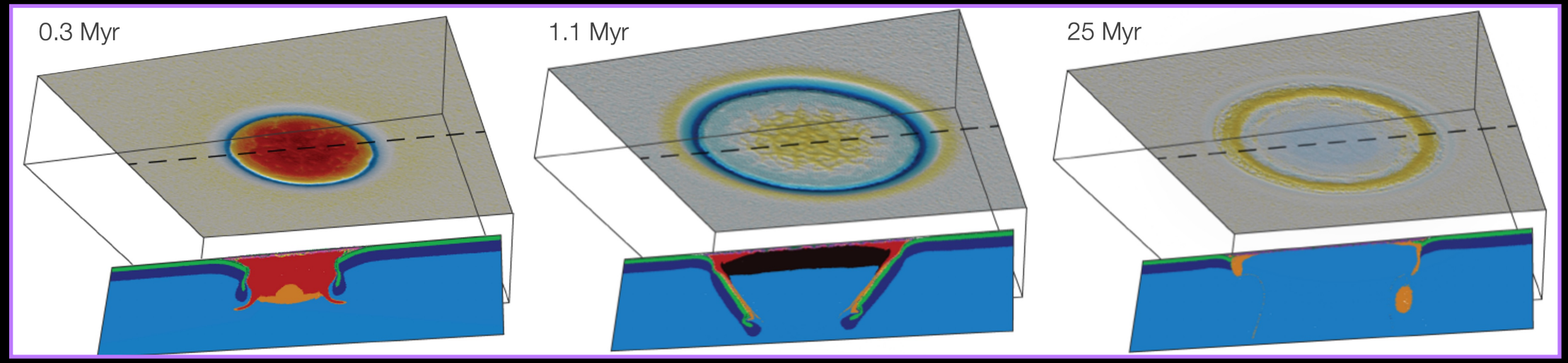
McGovern et al. (2013)

Lithospheric dripping





Plume penetration into lithosphere → **Lithospheric dripping** or **Short-lived subduction** → Plume cooling and topographic inversion



Composition

solid/molten
Upper crust (basalt)
Lower crust (grabbro)

solid/molten
Newly formed crust
Lithosphere

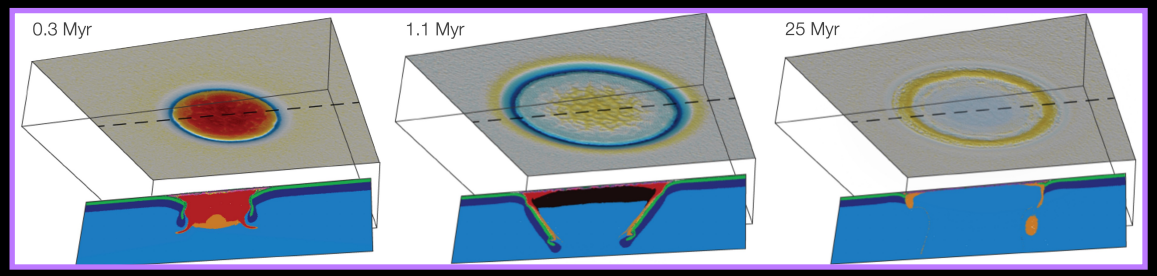
solid/molten
Mantle
Mantle plume

Topography [km]
-3 -2 -1 0 1 2 3

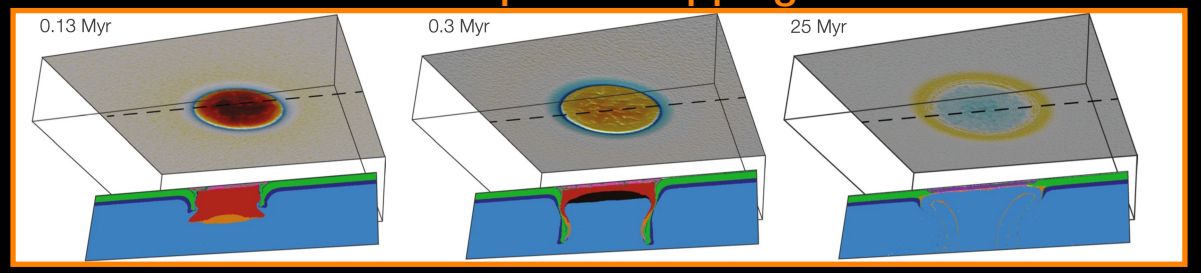
Published in Gülcher et al. (2020) *Nat. Geosc.*

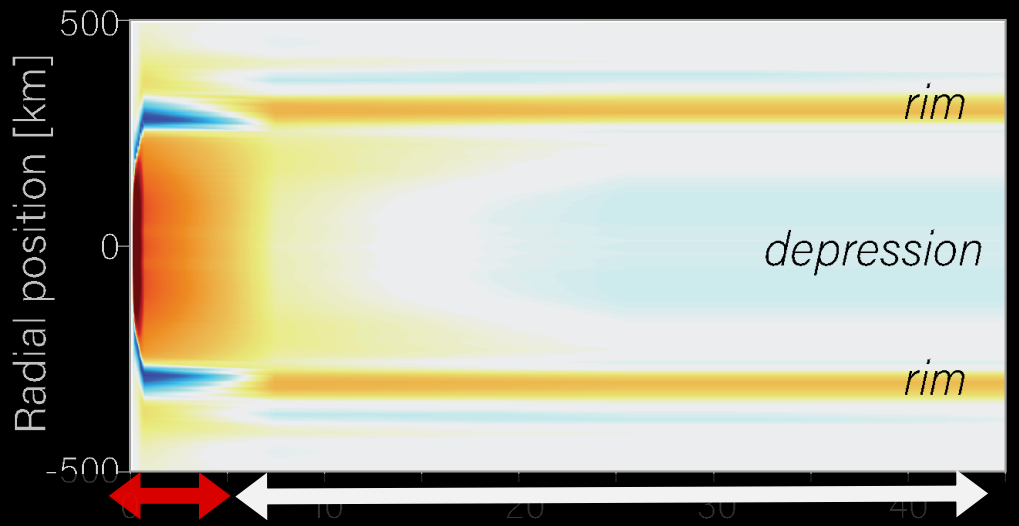
Topographic inversion

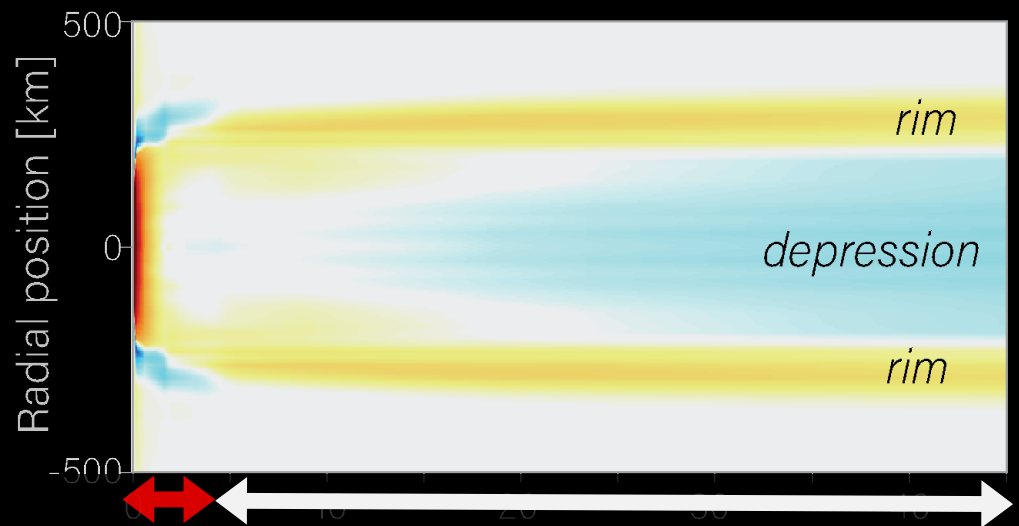
Short-lived subduction



Lithospheric dripping



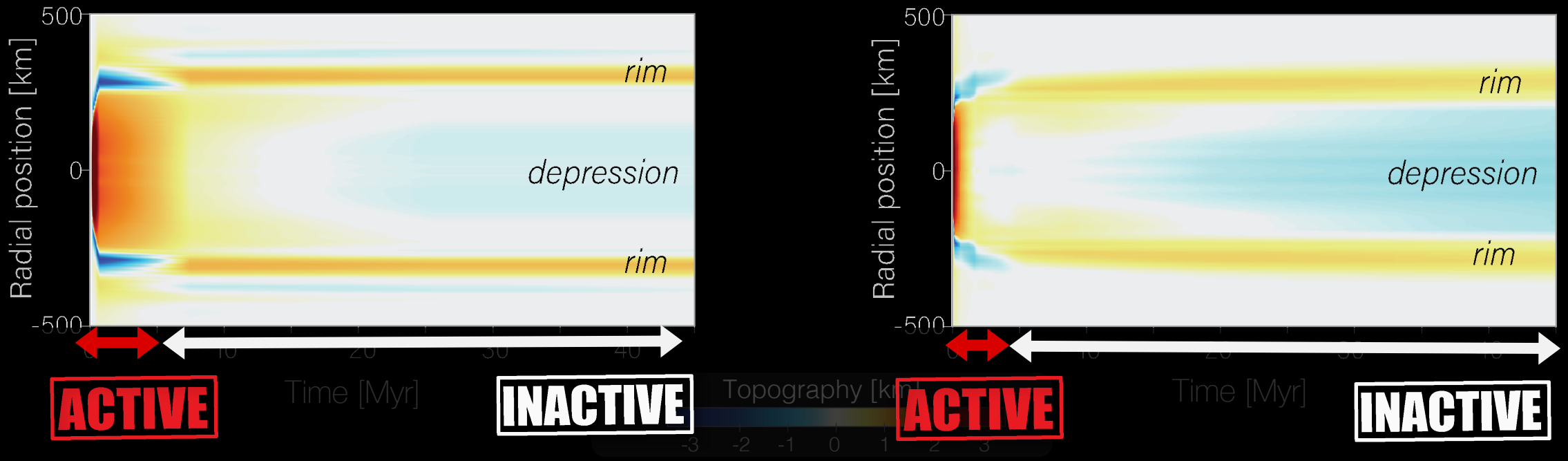




Topography [km]
-3 -2 -1 0 1 2 3

Topographic inversion

- Crustal thickness variations eventually lead to an isostasy-driven **topographic inversion**
- The topographic pattern of coronae is therefore **indicative** for **plume (in)activity**



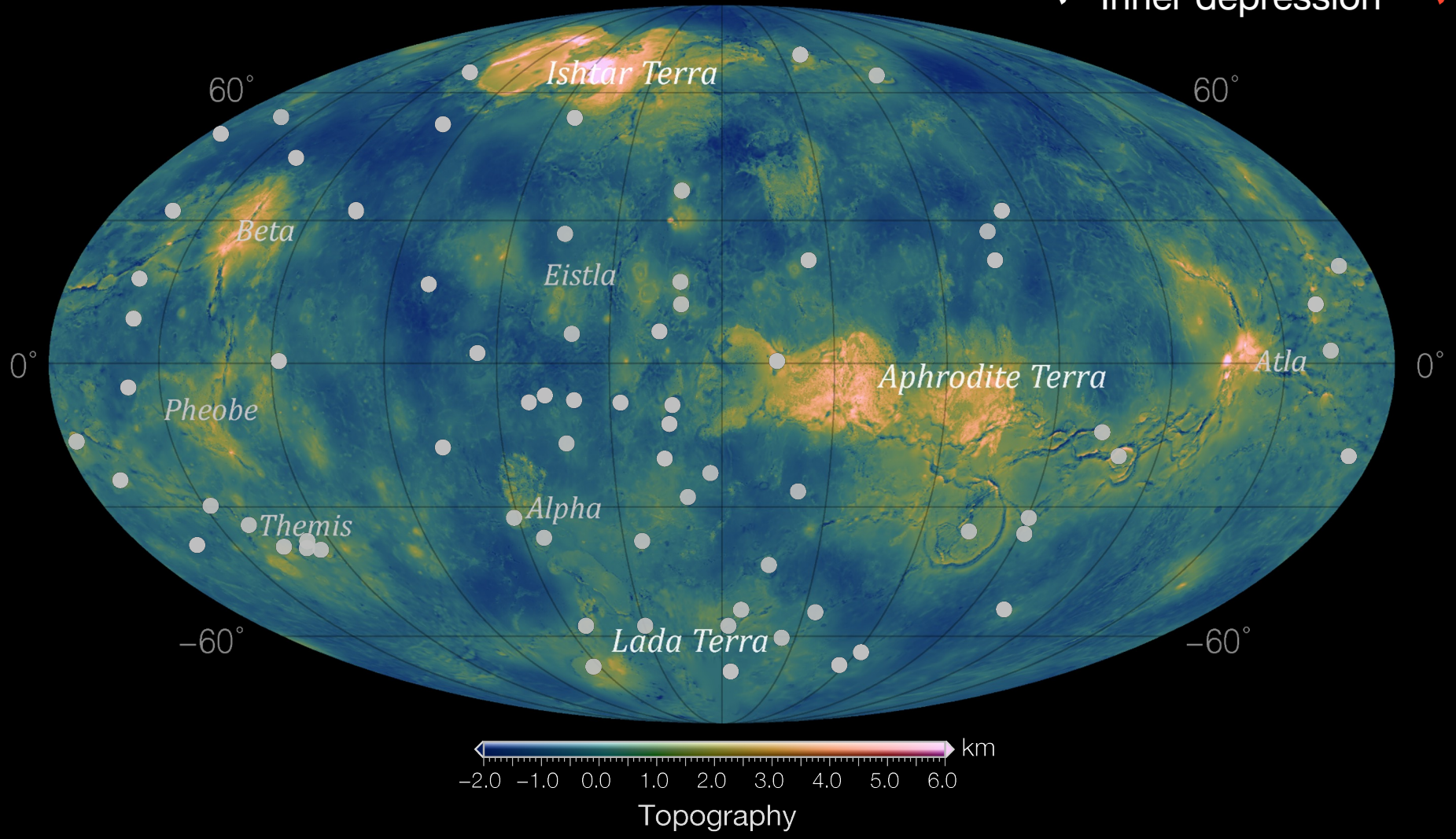
Coronae classification

INACTIVE

- ✓ Outer rim
- ✓ Inner depression

ACTIVE

- ✓ Outer trench
- ✓ Outer rise



Thouris corona (6.5°S, 12.9°E)

INACTIVE

50 km

ssification

Ishtar Terra

eta

Eistla

Aphrodite Terra

Themis

Alpha

Lada Terra

Aramaiti corona (25.5°S, 2.0°E)

ACTIVE

100 km

Rim

Depression

50 km

1.5 -1.0 -0.5 0.5

Topography [km]

Outer rise

Trench

Rim

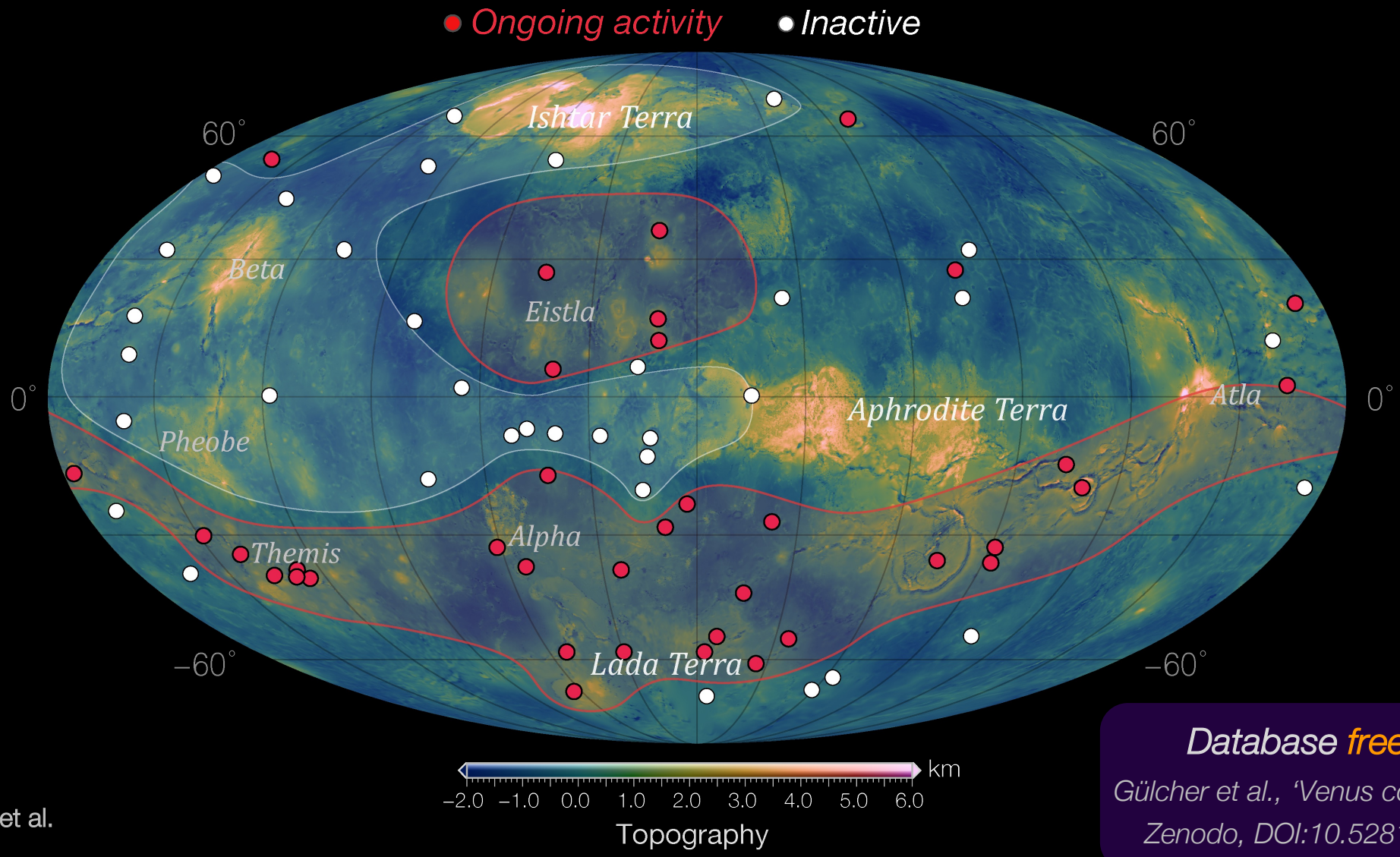
Inner dome

100 km

-1.5 -1.0 -0.5 0

Topography [km]

Coronae classification



Published in **Gülcher et al.** (2020) *Nat. Geosc.*

Database freely available:

Gülcher et al., 'Venus coronae classification', Zenodo, DOI:10.5281/zenodo.3608692

Integration with other surface features

Rifts

Subduction?

Volcanoes

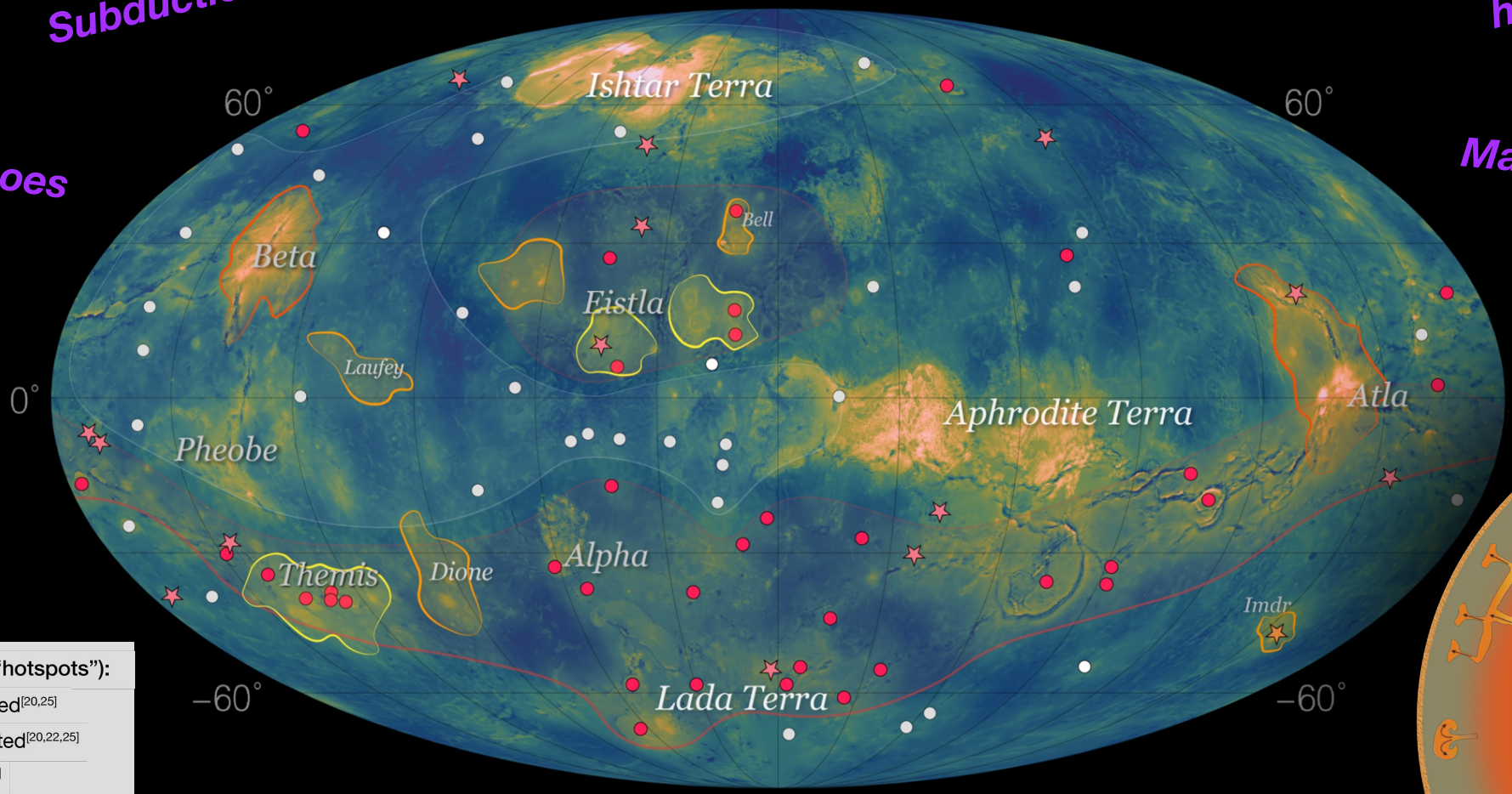
Novae

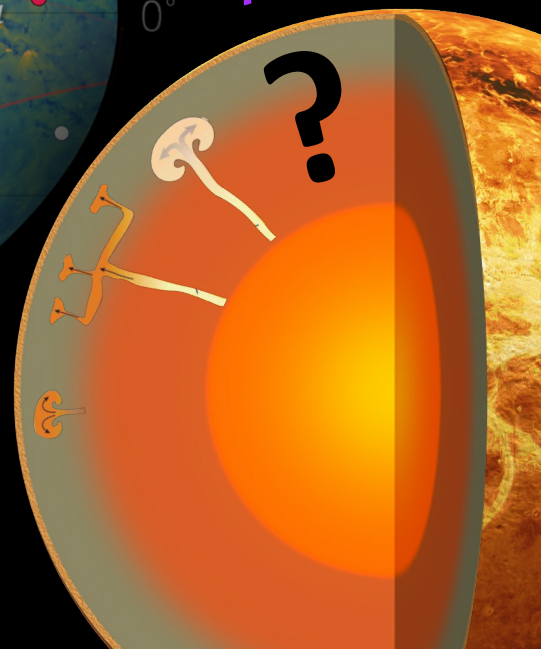
Lava flows

Tesserea highlands

Mantle convection

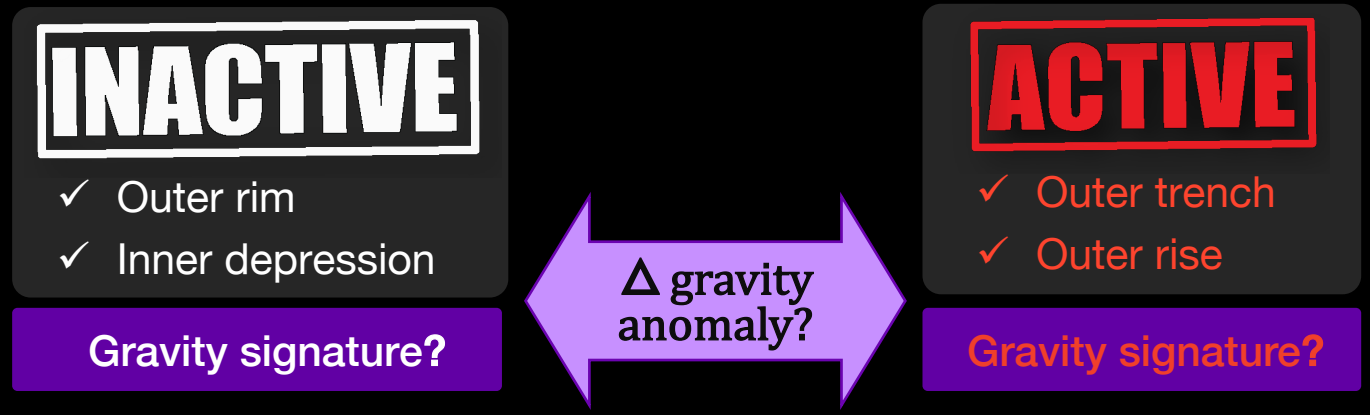
"Hotspots"





Gravity signatures

- How would (active/inactive) coronae be resolved in the **gravity field**?



Gravity signatures

- How would (active/inactive) coronae be resolved in the **gravity field**?

→ calculate **anomalies** of lithostatic pressure in our models

INACTIVE

✓ Outer rim
✓ Inner depression

Gravity signature?

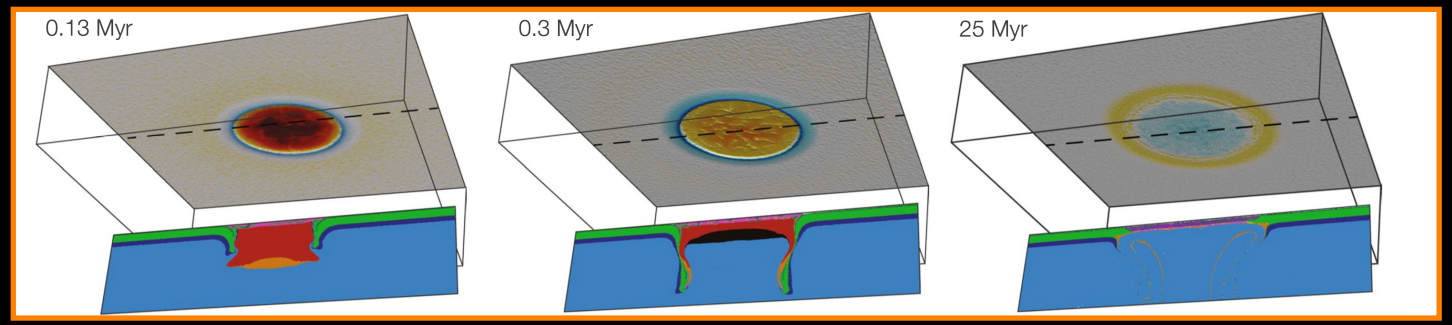
Δ gravity anomaly?

ACTIVE

✓ Outer trench
✓ Outer rise

Gravity signature?

$$\int_{bottom}^{top} \rho(z) g dz$$



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Gravity signature?

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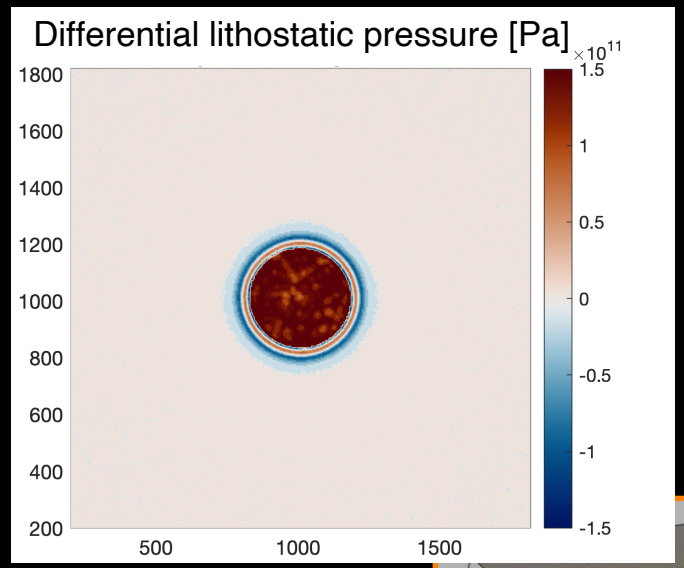
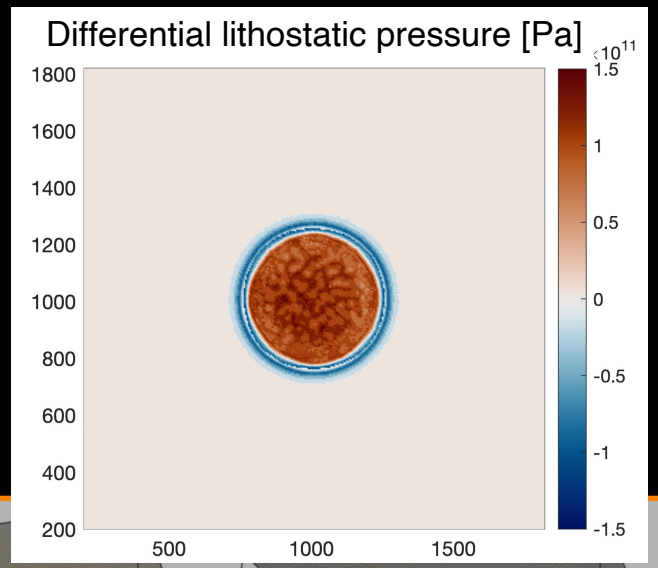
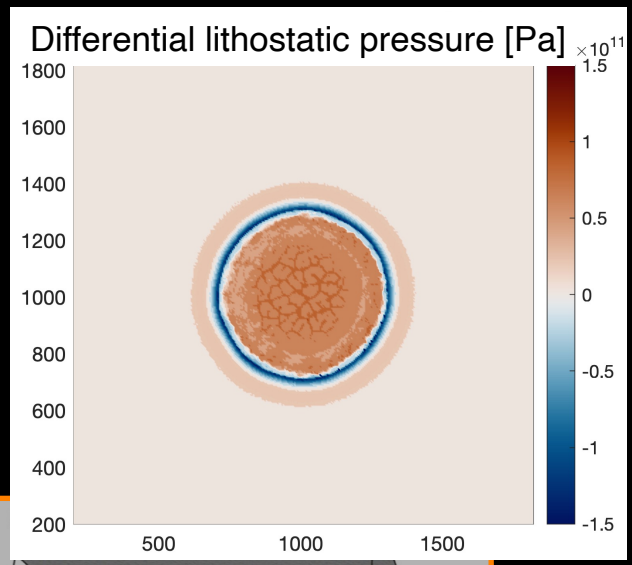
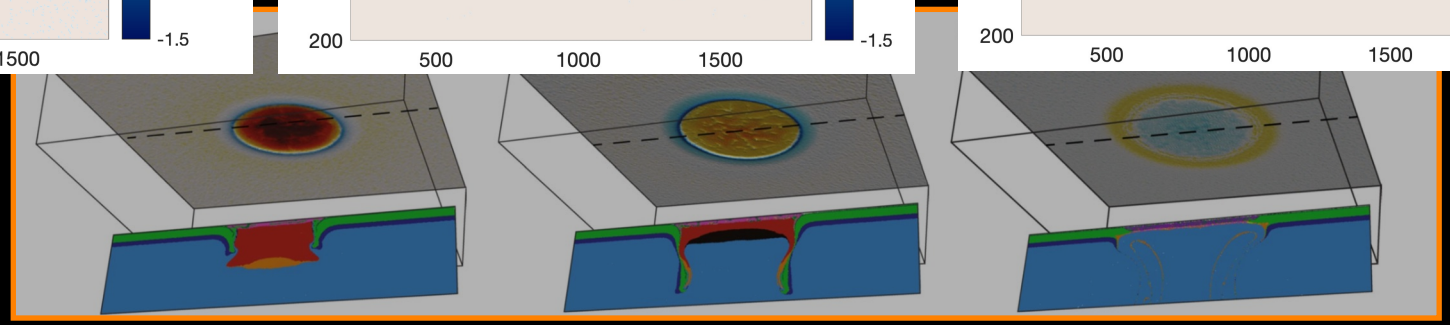
Gravity signature?









$$\int_{bottom}^{top} \rho(z) g dz$$

Stay tuned!

Towards the ‘Decade of Venus’

- **Coronae** may give insights into **volcano-tectonic** history and current state of Venus
- (Numerical) **modelling** key for better understanding (corona) tectonic processes
- Understanding how (**active/inactive**) geological features would be resolved in the **gravity field** is key for future Venus missions

Shukrayaan-I (IN)

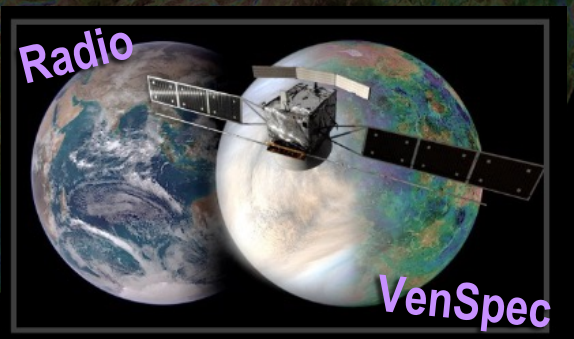
2024

VERITAS (NASA)

2028

DAVINCI+ (NASA)

2029



ENVISION (ESA)

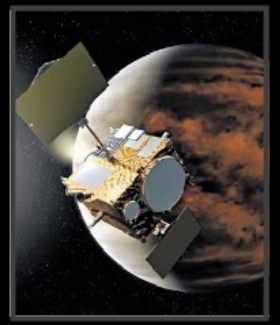
2031

Towards the 'Decade of Venus'

Radio (EnVision/VERITAS)

Radio science:

- Better deduce Venus' **lithospheric** and **crustal** structure
- Can geologically-**active** structures be distinguished in the gravity field?
- Fossil coronae signature of thin crust + interior depression[10] should be **detectable** in gravity signature
- What is the **resolution** needed in these instruments to be able to distinguish active vs. inactive features?



Shukrayaan-I (IN)

2024

VenSpec (EnVision) **VenSar** (VERITAS)

Radar imagery:

- Detect **active deformation** (e.g., lava flows) by repeat pass observation:
- Are **raised novae** tectonically active, as proposed by modelling studies[13]? (e.g., Idunns Mons)
- What is their **relation** to coronae?

Topography:

- Assessment of **unresolved**/possible **wrongly-resolved** features in past mission data

VERITAS (NASA)

2028

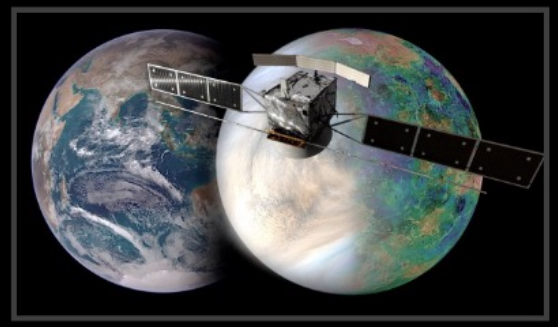
VenSpec (EnVision) **VEM** (VERITAS)

Spectroscopy:

- Surface **mineralogy** and texture (→related mantle source composition)
- Have numerical models been using acceptable rock types and physical properties?
- Detect **current volcanic eruptions** by repeated imagery of surface thermal emision
- Relate volcanic sites to "**hotspots**"

DAVINCI+ (NASA)

2029



ENVISION (ESA)

2031