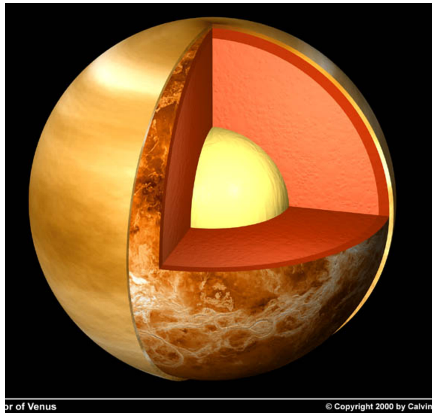

Geodesy and ephemeris experience with EnVision

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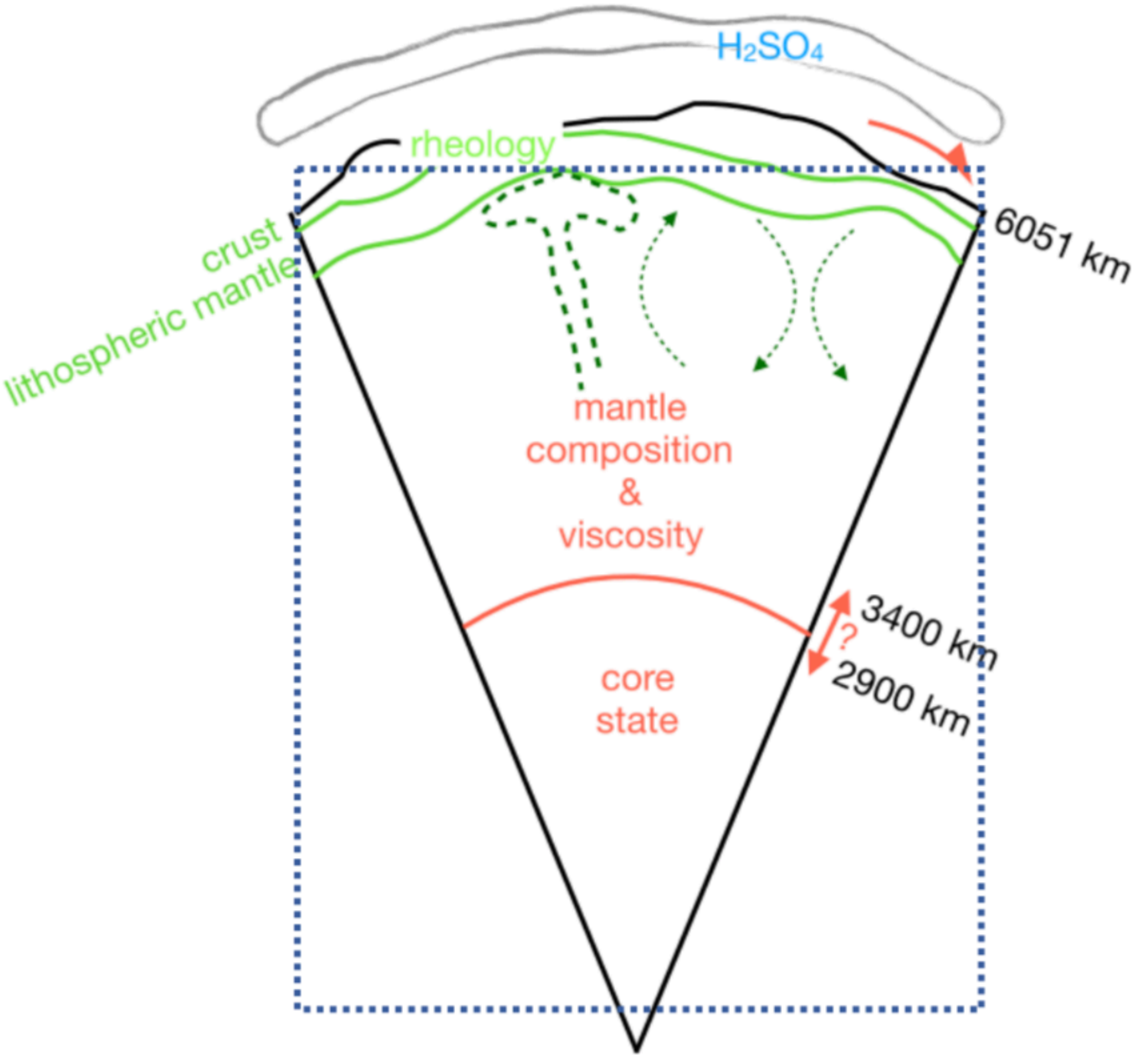
International Venus Conference, May 31st – June 3rd 2019, Niseko, Hokkaido, Japan

EnVision radio-science experiment



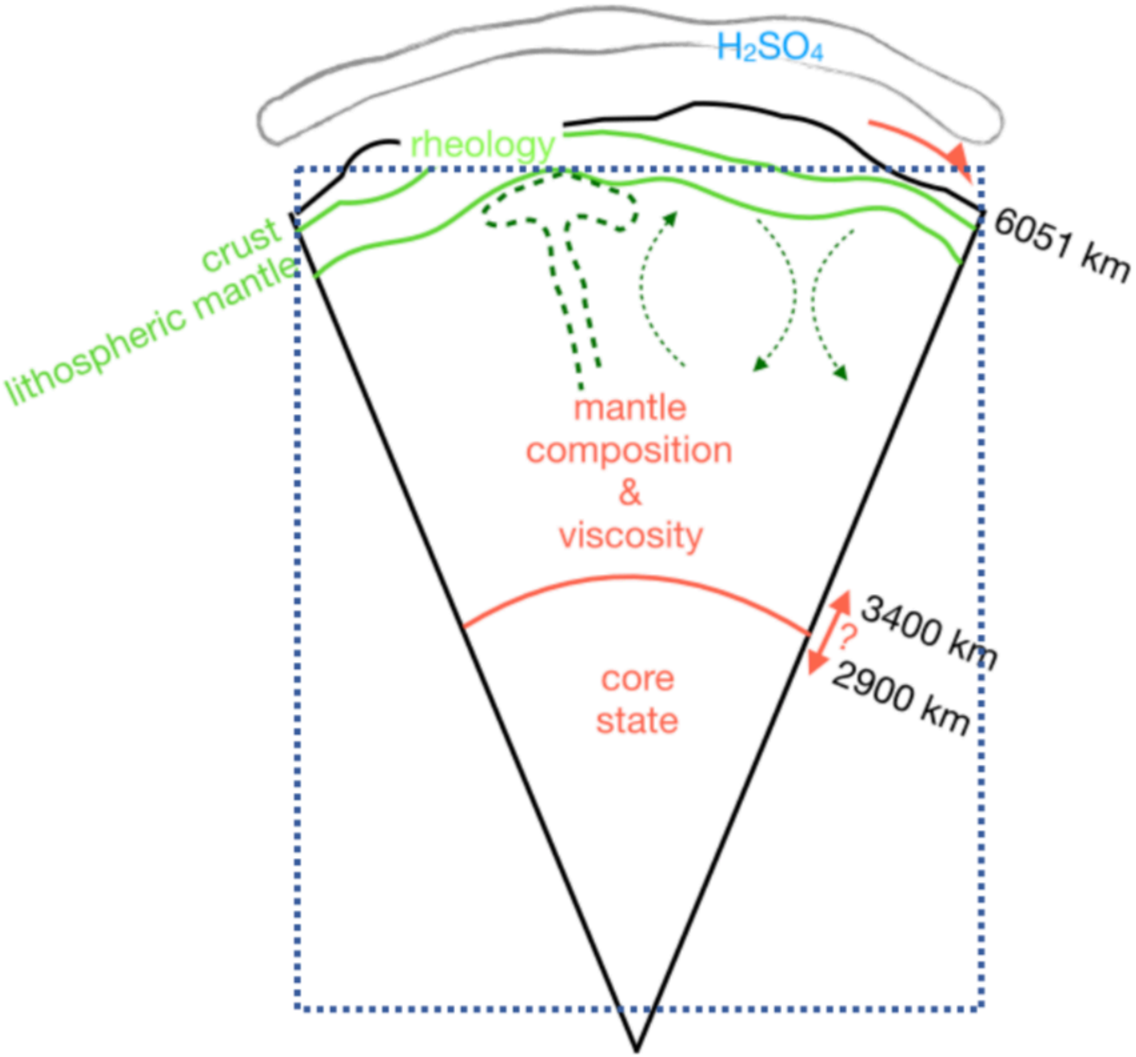
Main goals

- ❑Venus' interior structure
- ❑Monitoring atmosphere

  See Tellmann et al. *Poster P53*
- ❑Additional opportunity:

  Fundamental physics, Sun's gravity

EnVision radio-science experiment



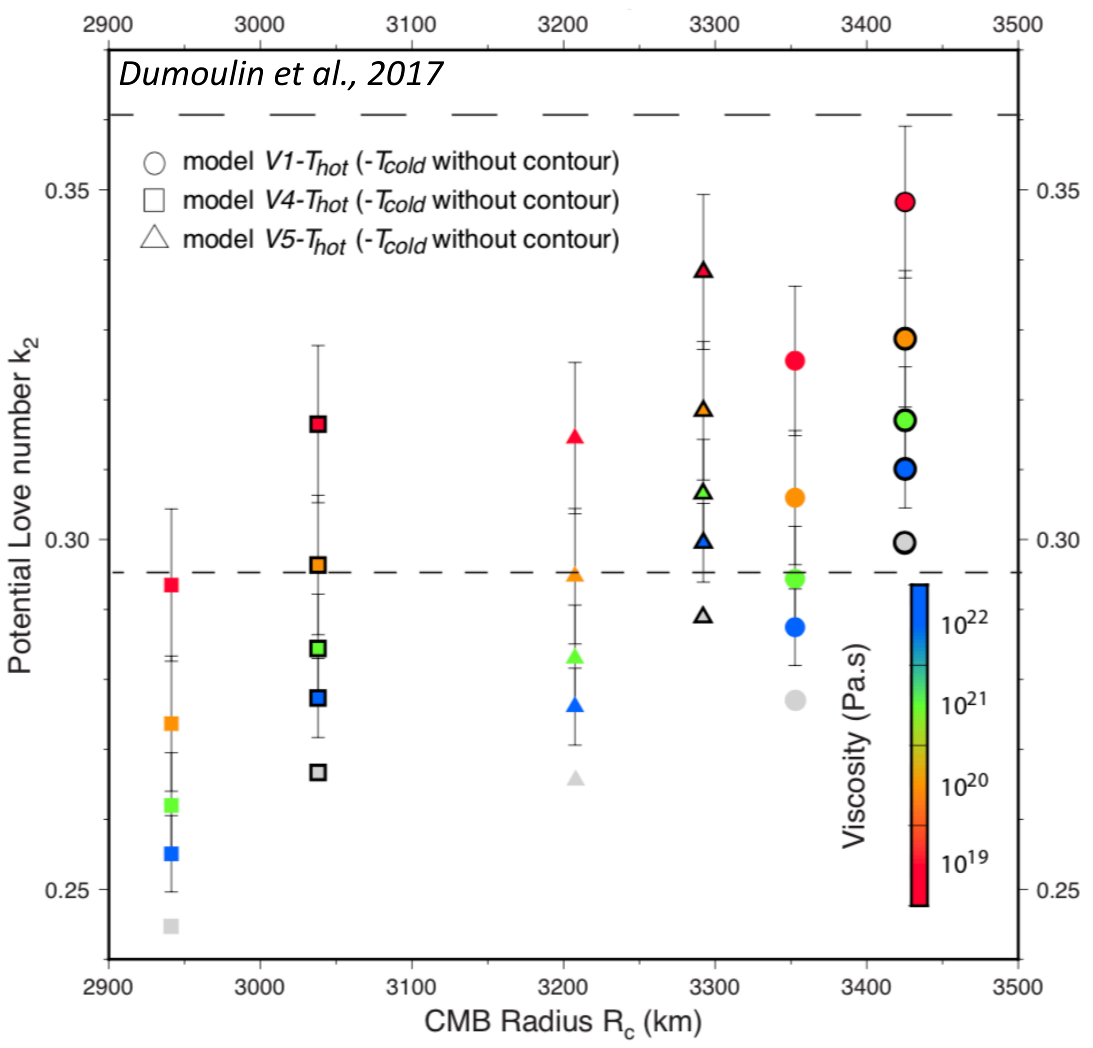
Interior structure from the gravity experiment

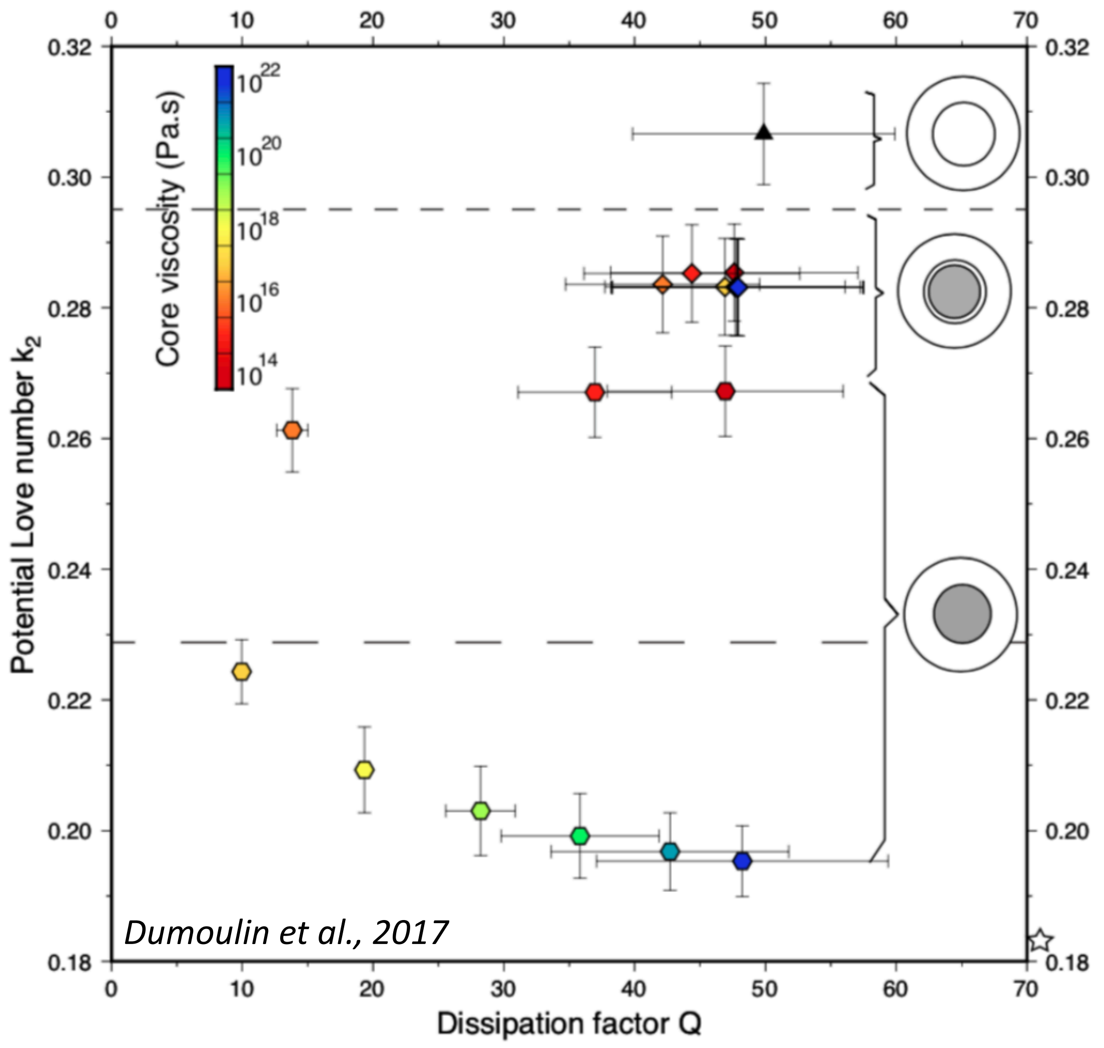
- Size and state of the core ?
- Mantle viscosity ?

- Thermal evolution of the planet

Measurement: $\boldsymbol{k_2}$ tidal potential Love number

Current knowledge of Venus interior

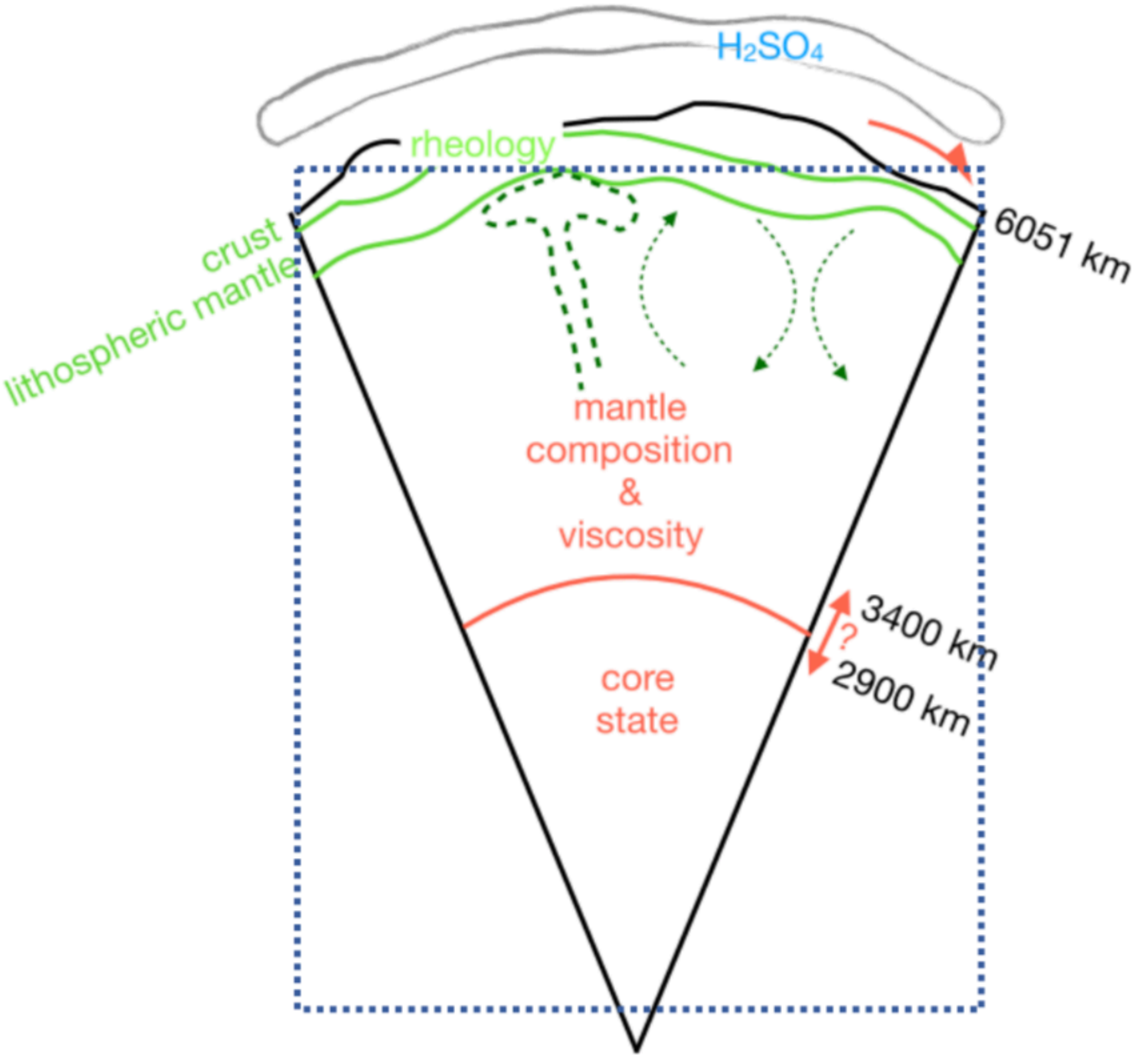




k_2 required accuracy of 0.01 (3.4%)

(current precision: 22%)

EnVision radio-science experiment

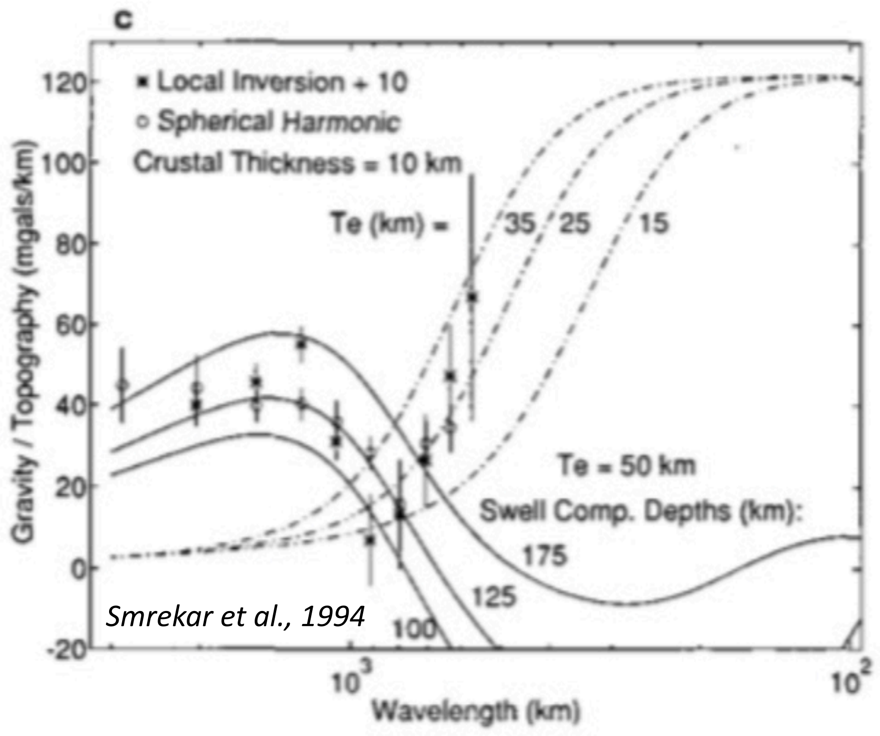


Interior structure from the gravity experiment

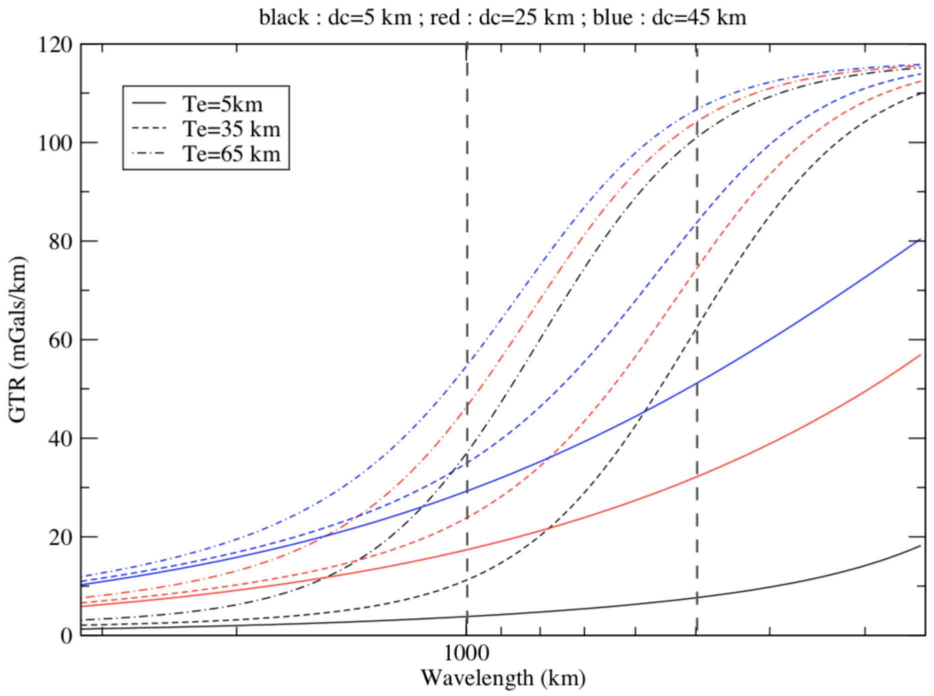
- Lithospheric and crustal thicknesses
- Topography compensation mode (dynamic/isostatic/elastic)
- Geological evolution of the planet

Measurement: - ***Mapping gravity field*** at spatial resolution of 200 km (or better)
Variations among geological features and various places
- ***topography***

Current knowledge of the gravity-to-topography (GTR) ratios



- Gravity/topography on *Bell regio* from Magellan data: accuracy > 10 mGal/km for wavelength > ~ 700 km.

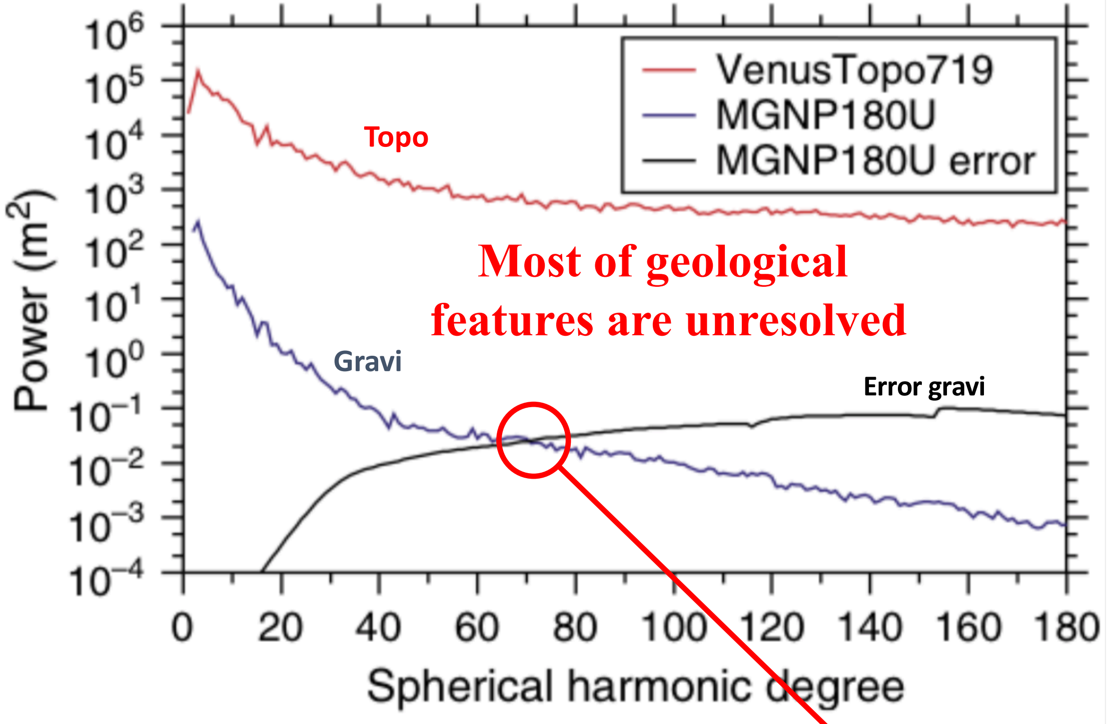


- Simulation of GTR from various lithospheric elastic thickness (Te) and crustal thickness (Tc) (colour of curves).

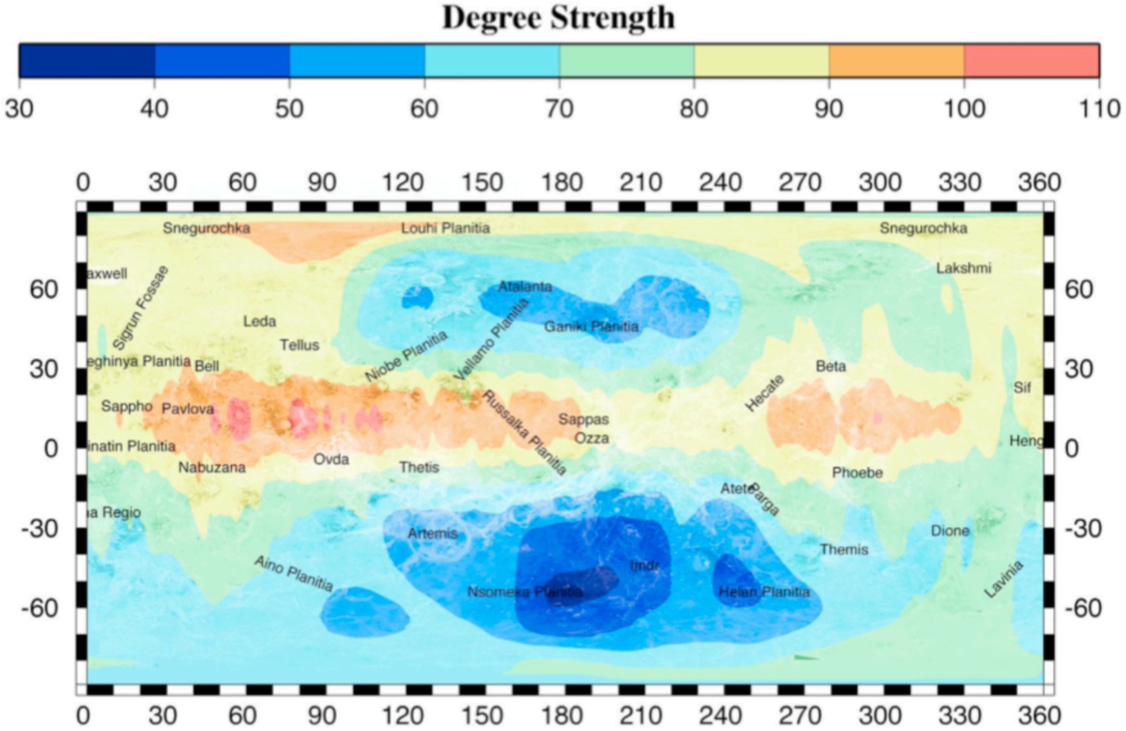
➢ **Accuracy of at least 20 mGal/km is required to decipher among models.**

Current knowledge of Venus gravity field

Wieczorek, TOG, 2015



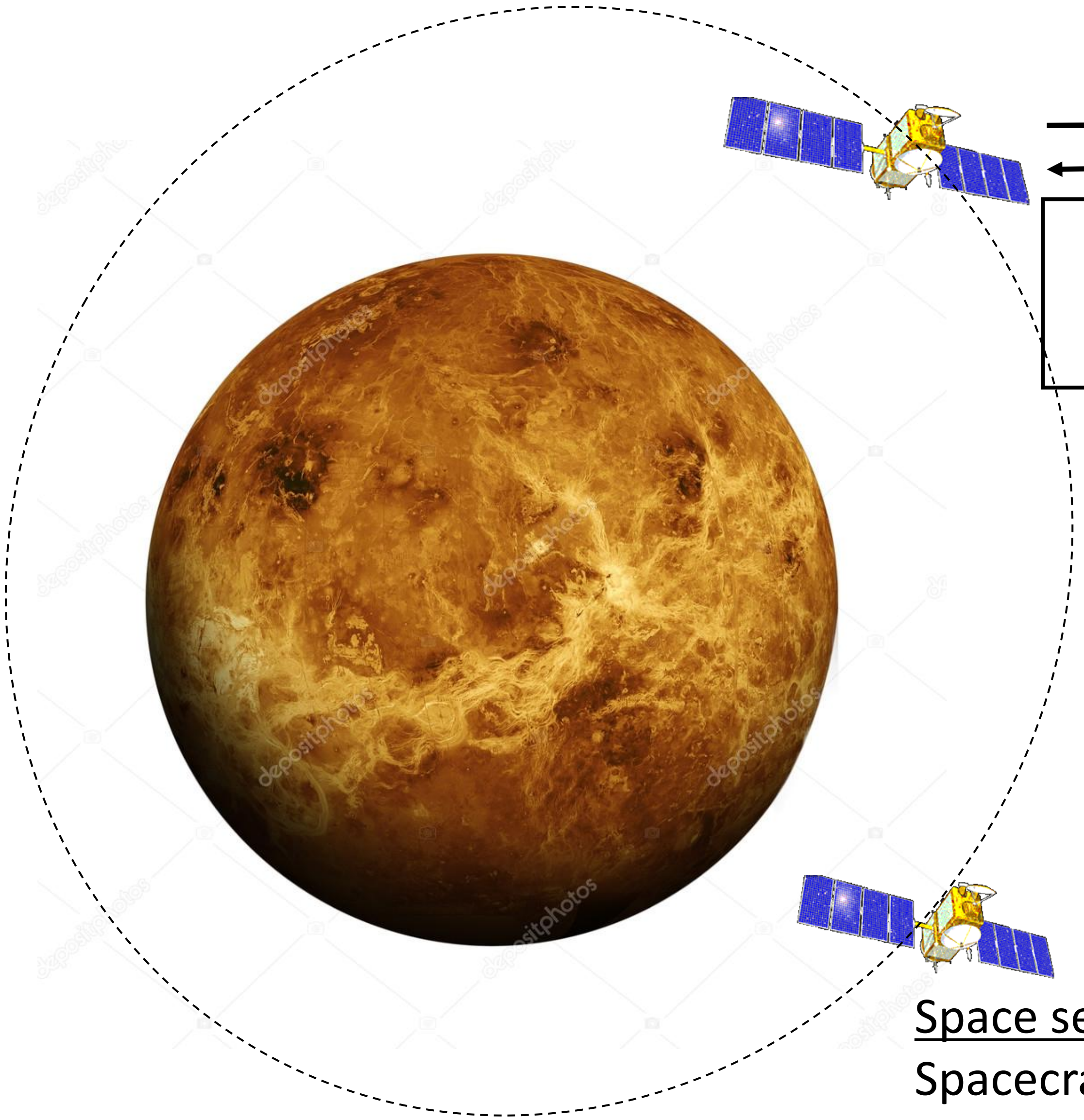
Max. Degree 180 but degree strength **70** (or 270 km spatial resolution) on average

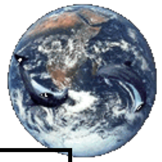


Geographical variations of degree strength due to Magellan elliptical orbits:
- Best (red): 110 (170 km) – Worst (blue): 30 (620 km)

✓ Goal of EnVision gravity experiment: **Degree strength of 90 (210 km) on average (better in the southern hemisphere thanks to the lowest altitude part of the EnVision orbit).**

Principle of the gravity field determination





2-way coherent Doppler tracking:
X(up) – X/Ka (down)

Ground segment:
ESTRACK (DSN) deep space tracking stations

- ***Monitoring the free-fall orbital motion of s/c in the gravity field of the planet***
- ***Deriving the gravity field from this reconstructed s/c orbit***

Space segment:
Spacecraft coherent radio-transponder (system)

EnVision gravity experiment: Current design

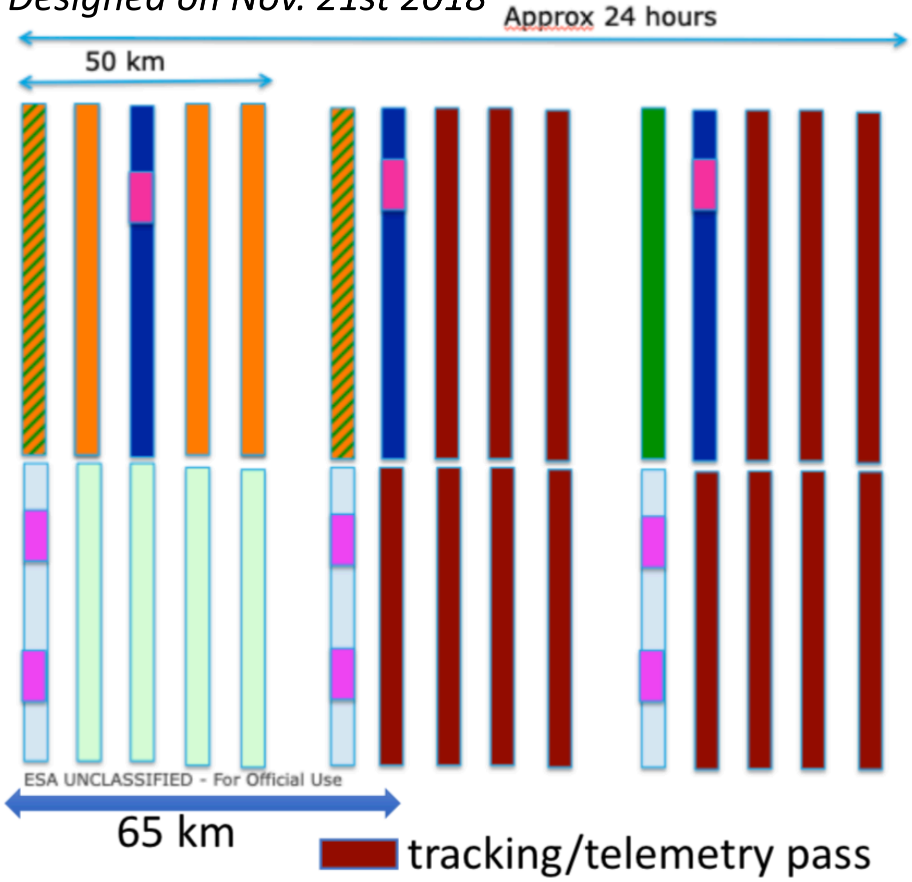
- **Radio-tracking scheduled for navigation can be used for radio-science experiment.**
  (usually performed for Mars gravity with NASA's s/c and being realized with ESA's ExoMars2016)

So, the radio-transponder for radio-navigation is used as the space segment for the RS exp.

- Current EnVision configuration for radio-links (under study):

  1) **Frozen eccentric orbit (220-470 km),**
     88° inclination orbit – Pericenter at **-65° latitude**
  2) **On average 7.5 hours** of tracking slot per day
     (during telemetry)
  3) **Doppler X (up) / X+Ka (Down)**:
     sampling 10 sec; **Noise 0.03 mm/s**
  4) 1 WoL event per day, ΔV(residual)=0.2 mm/s
     (during tracking)

Designed on Nov. 21st 2018



Importance of Spacecraft force model

- Gravitational forces:
  - A priori Venus' static gravity field (updated model from Magellan tracking data)
  - Tidal gravitational potential: k_2 Love number
  - Point mass representation of other solar system bodies using planetary ephemerides.

- Non-gravitational forces :
  - Atmospheric drag (a priori high altitude atmospheric density model)
  - Direct solar, albedo & IR pressure radiations.
  - Residual accelerations (or residual Δ V) induced by each unbalanced wheel off-loading (WoL) or angular moment desaturation event.

➢ Study of the effect of EnVision tracking configuration and desaturation events on the gravity field & k_2 solutions

Simulation Process

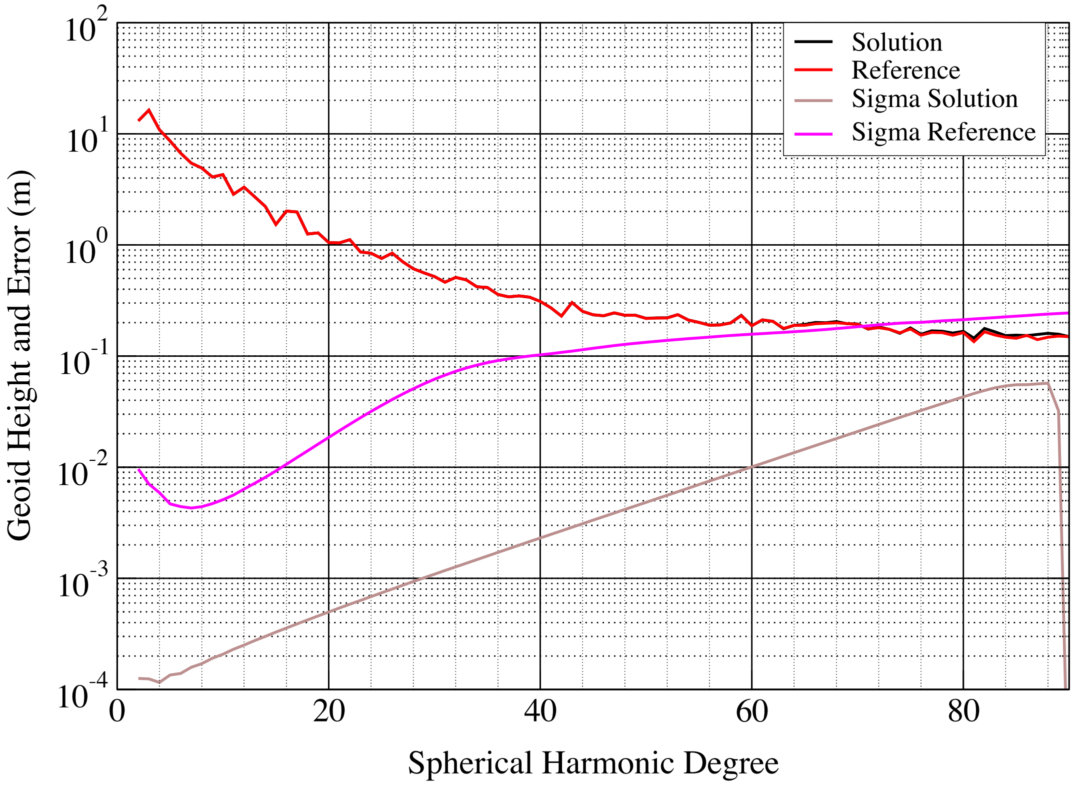
<u>Initial configuration:</u> Orbit 220 km x 470 km and 88°
Successive 4-days data-arcs covering up to 4 Venusian days
Initial gravity field: JPL, 180x180 model
Daily desaturation event: Δ V of 0.2 mm/s

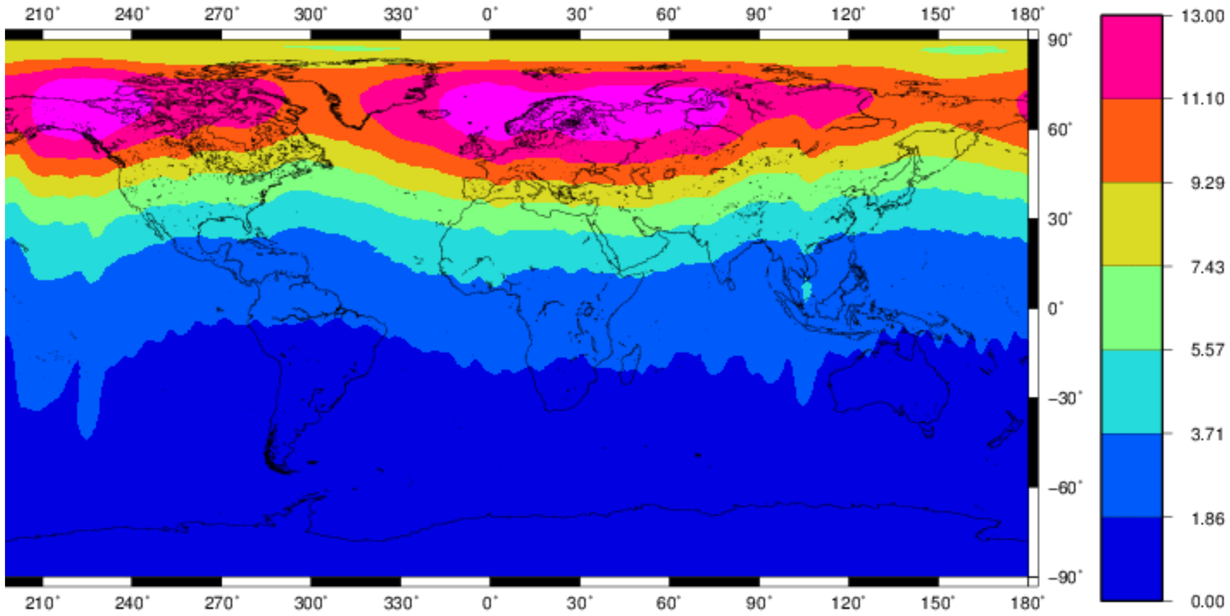
Simulated X/X-Ka Doppler data (10sec sampling time) with white noise (0.03 mm/s).

<u>Fitted parameters per arc:</u>
Initial state vector (position/velocity) of spacecraft at the beginning of the data-arc and
Δ V at each desaturation event.

<u>Fitted parameters after stacking together all data-arcs:</u>
Gravity field, k_2 tidal Love number and again all parameters per arc

Simulation of EnVision gravity experiment: Preliminary results





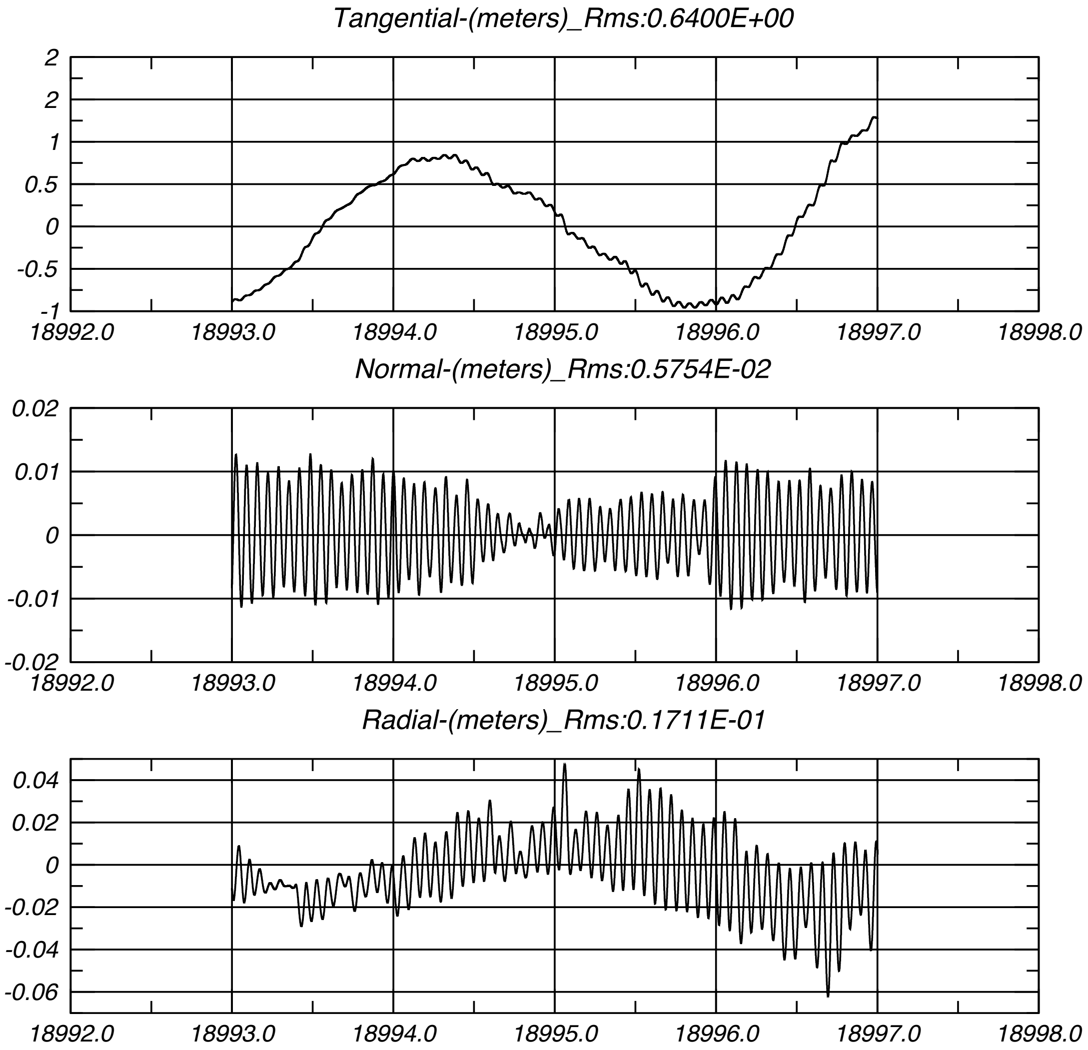
✓ Gravity error < 20 mGal everywhere

✓ Degree strength of 90 on average can be reached

✓ k_2 : precision of 0.08% << 3.4%

➢ ***Caution: The mis-knowledge of a priori non-gravi forces & gravity NOT taken into account***

Effect of inaccuracy of non-gravitational force model on the EnVision orbit

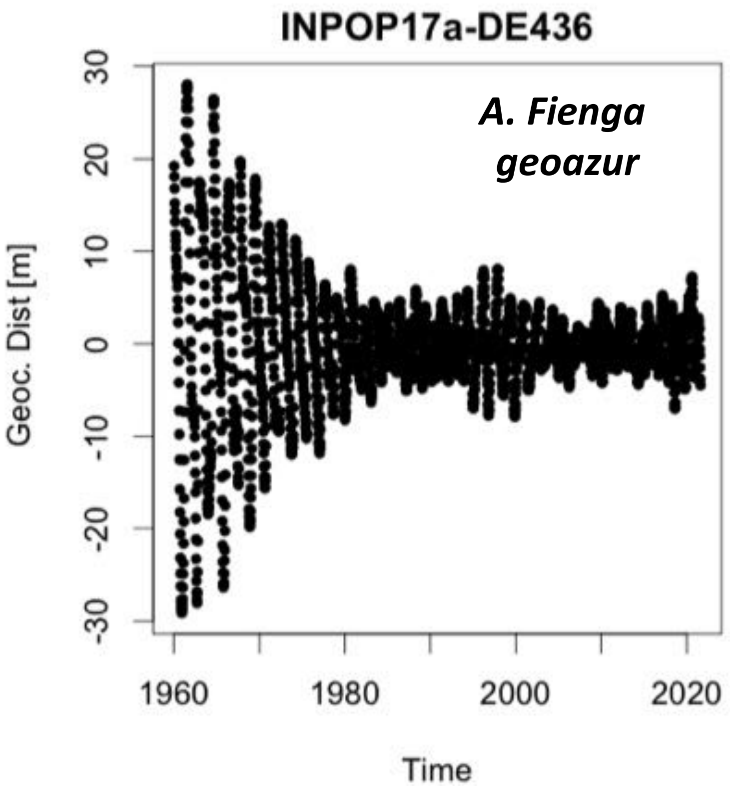


- ✓ Perturbation of atmospheric drag (100%): ~2-days along-track signal that can mimic gravity signature

- ✓ More **realistic simulations** are required to predict **reliable accuracy** on gravity field and k_2 solutions from **EnVision radio-science** experiment

→ Work in progress

Opportunity: Improvement Venus ephemeris



- *Venus orbit error : 10 meters*

- Improving Venus ephemeris using 2-way ranging (round-trip light time) between spacecraft and tracking stations.
- At least 10 minutes every 12 hours over 4 Venusian days.
- 50 cm uncertainty on ranging measurements
- Fitting parameters of the INPOP model:

<u>Sun gravity:</u>

GM at ± 3.8E-17

J_2 at ± 3.8E-10

<u>Fundamental Physics:</u>

PPN β at ± 4.3E-7, PPN γ at ± 1.8E-6

G_dot/G at ± 5.2E-16

- 15-20% improvement wrt current knowledge
- Simulations assuming merging with Bepi-Colombo ranging data

Summarizing EnVision radio-science experiment

- Monitor the atmosphere → S. Tellmann et am.'s **poster P53**

- Gravity experiment aims to better constrain interior structure by improving the gravity field resolution (200 km) and accuracy (20 mGal) as well as the k_2 Love number (3% of error)

- Use of radio-links between spacecraft and Earth (during telemetry)

- Preliminary simulations fit to the requirements but more reliable simulations are needed.

Work in progress