Contraindre la structure interne de Mars avec GINS

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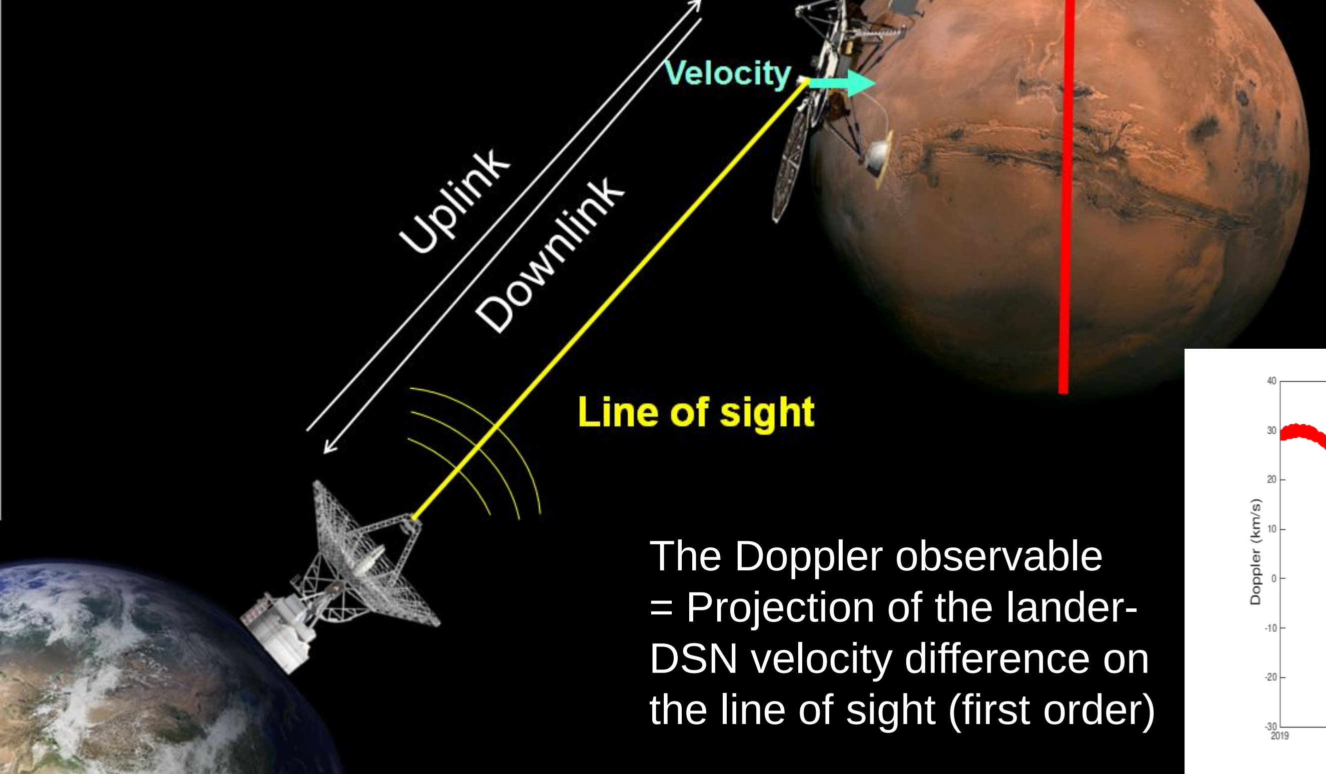
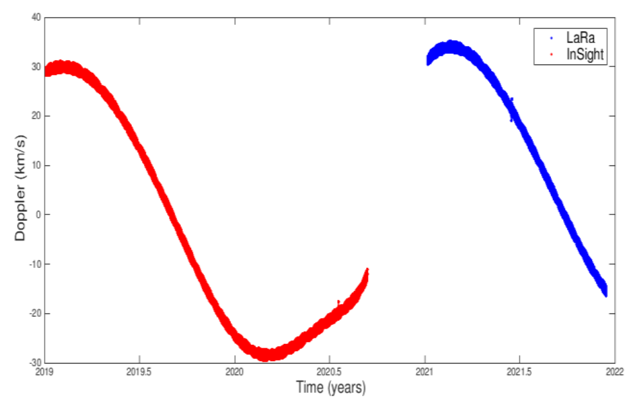
Context

- Radioscience experiment with a lander at the surface of Mars
- **Objective:** study the rotation and orientation of Mars

- Transponder on a stationary lander
- Direct to Earth X-band radiolink
- DSN antennas on Earth



The Doppler observable = Projection of the lander-DSN velocity difference on the line of sight (first order)

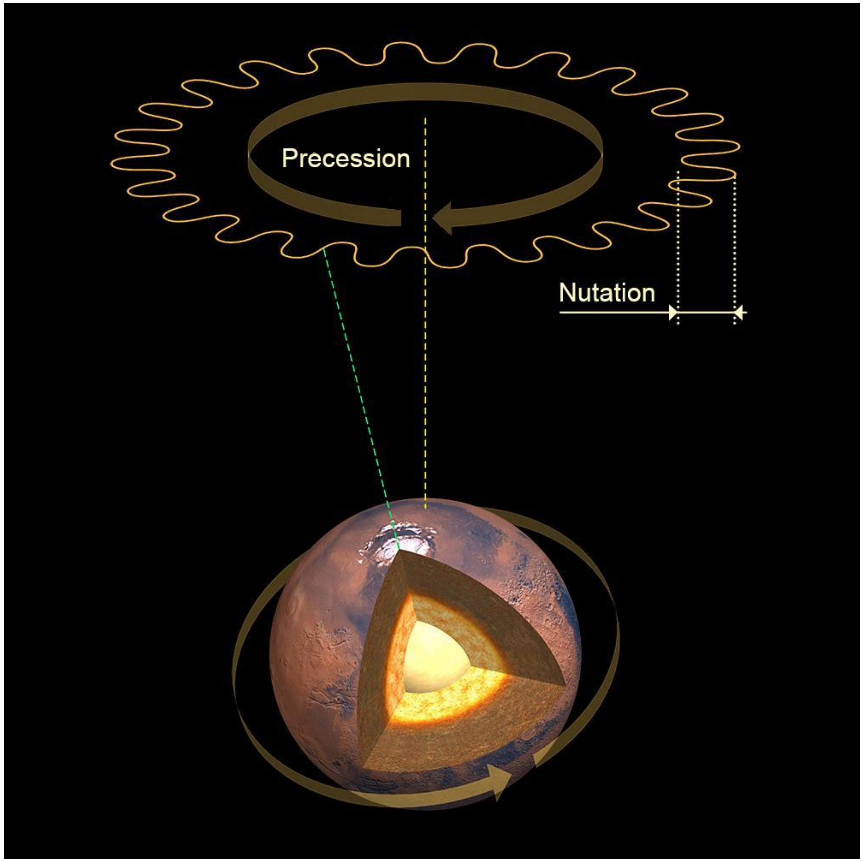


Mars rotation

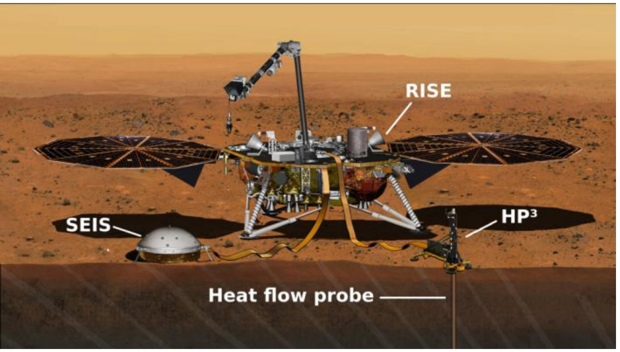
- Variations of Mars' rotation rate = Length-Of-Day variations (**ΔLOD**)
- Variations of the orientation of the rotation axis in space = **precession** (long term) + **nutations** (short term)

Rotation and orientation parameters = **MOP**

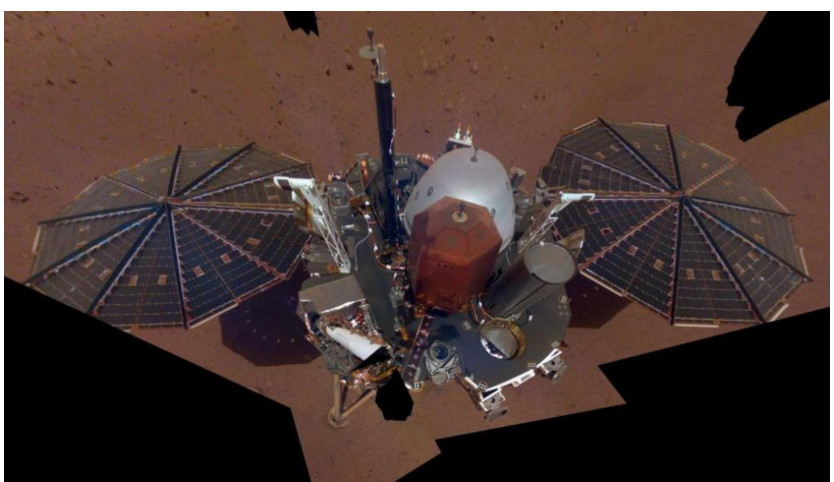
➔ Internal structure / CO_2 cycle



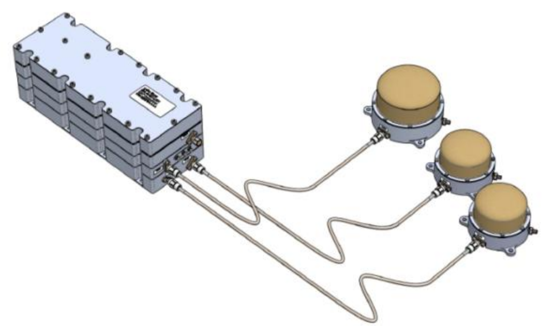
2 missions to Mars

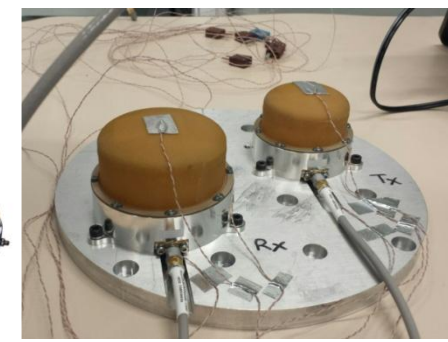


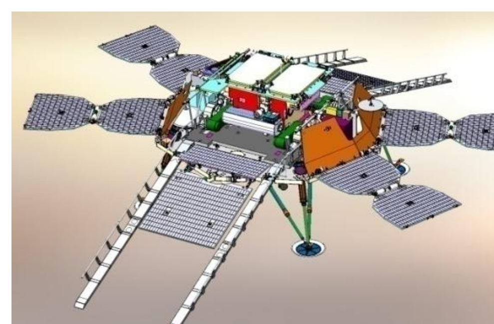
- NASA mission
- Landing: 26th november 2018
- RISE transponder (Rotation and Interior Structure Experiment)



- ESA/RosCosmos joint mission
- Launch date: July 2020 (rover+platform)
- LaRa Belgian transponder (Lander Radioscience)







Method

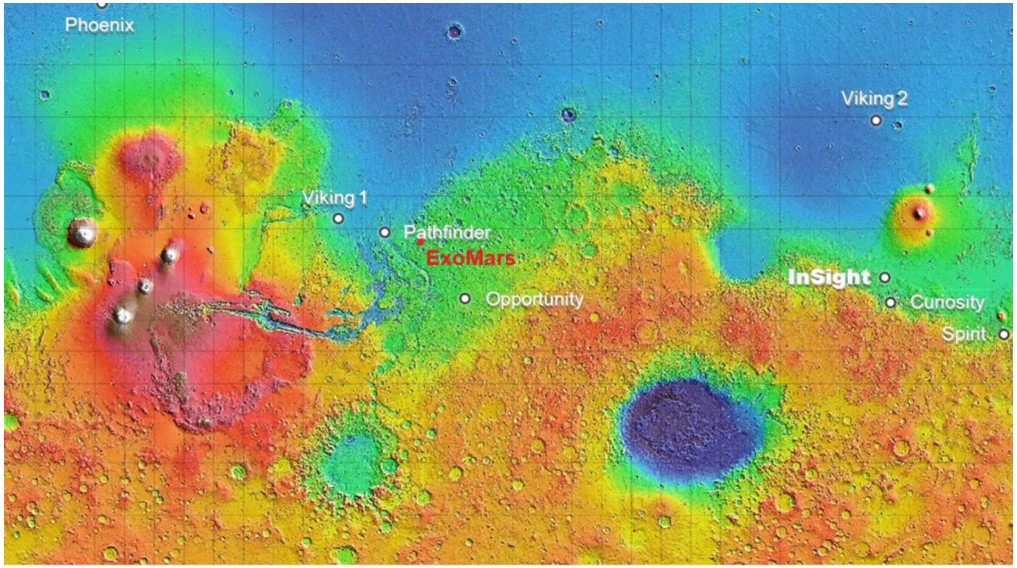
- Numerical simulations with GINS/DYNAMO to quantify the improvement in the determination of the MOP by synergy RISE/LaRa

- GINS
  - Simulations of the lander-Earth measurements + Doppler noise for RISE and LaRa

- DYNAMO
    - Stacking of normal equations (dynamo_c)
    - Inversion and resolution with additional constraints (dynamo_d)
  - Combination: RISE 700 days + LaRa 700 days successively

- Among all MOP of the Martian rotation model, we estimate:
  - Coordinates of lander position (X,Y,Z)
  - Precession rate
  - Obliquity rate
  - Annual and semi-annual amplitudes ΔLOD
  - Annual, semi-annual and ter-annual amplitudes of nutations

Operational characteristics



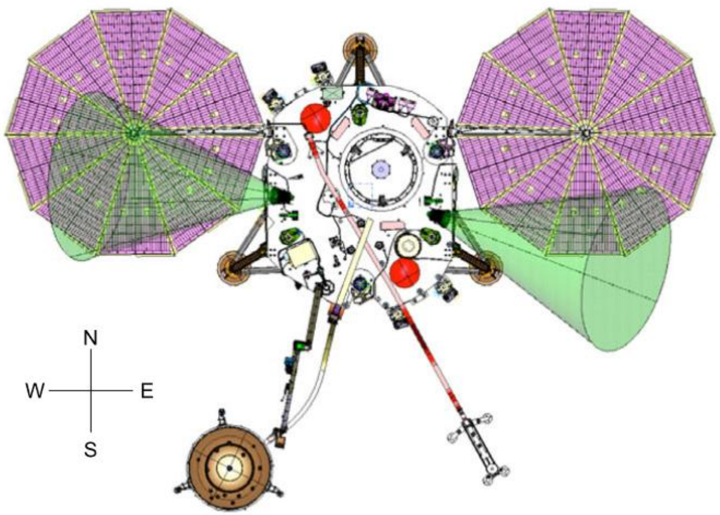
	RISE	LaRa
Mission	InSight	ExoMars 2020
Starting date	November 2018	Mars 2021
Landing site	Elysium planitia (4°N, 136°E)	Oxia Planum (18°N, 333°E)
Mission duration	700 days	700 days
Pass duration	60 min/day	45 min, twice per week
Earth elevation	[10°,30°]	[35°,45°]
Doppler noise	White noise 0.05 mm/s	
Earth stations	3 DSN stations	

InSight cases

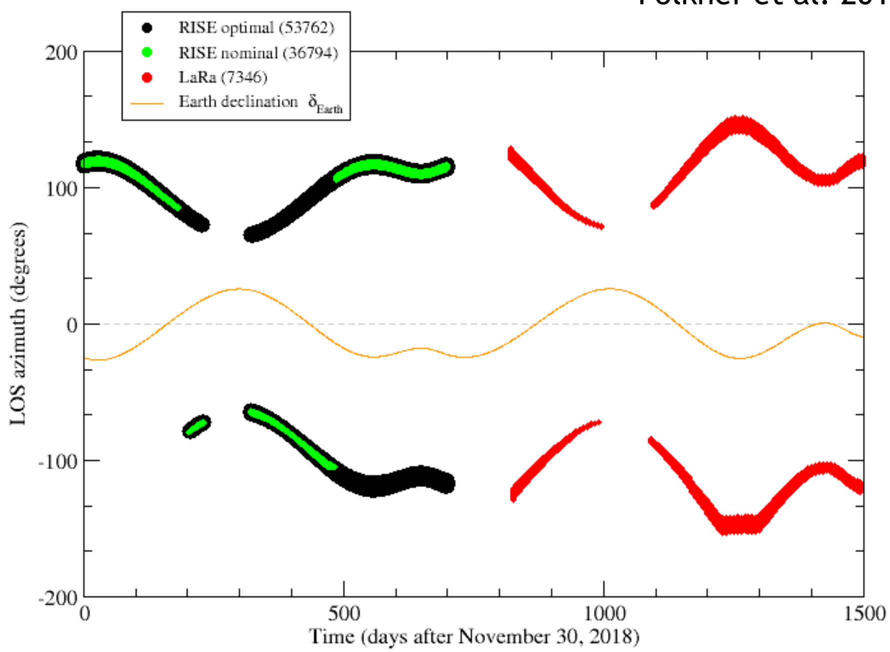
- Tracked only during the mornings for the first 200 days

- Optimal case
  Configuration planned before the landing (alternate east-west tracking after 200 days and unconstrained azimuth)

- Nominal case
  More realistic configuration: max. 25°off bore sight and 5° azimuthal offset

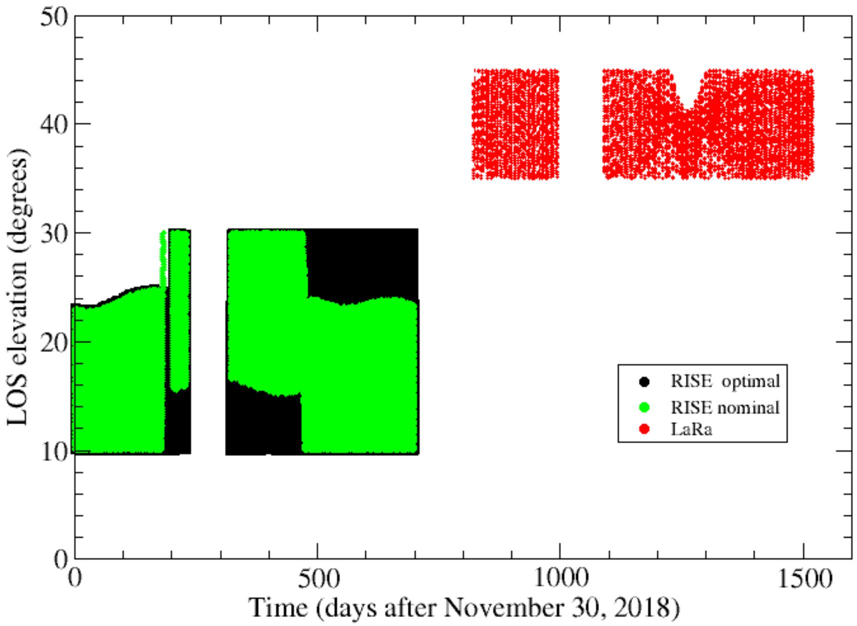


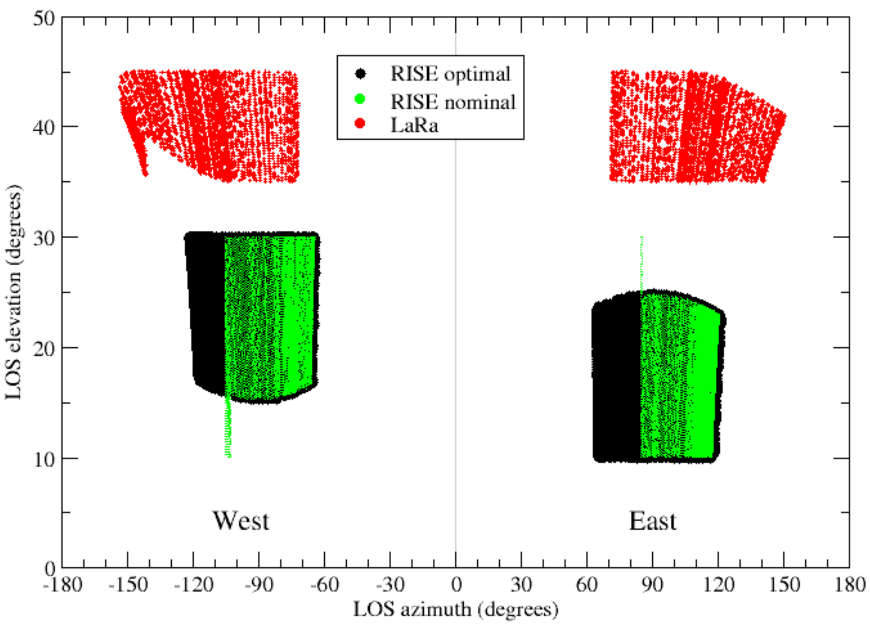
Folkner et al. 2018



Simulations setup

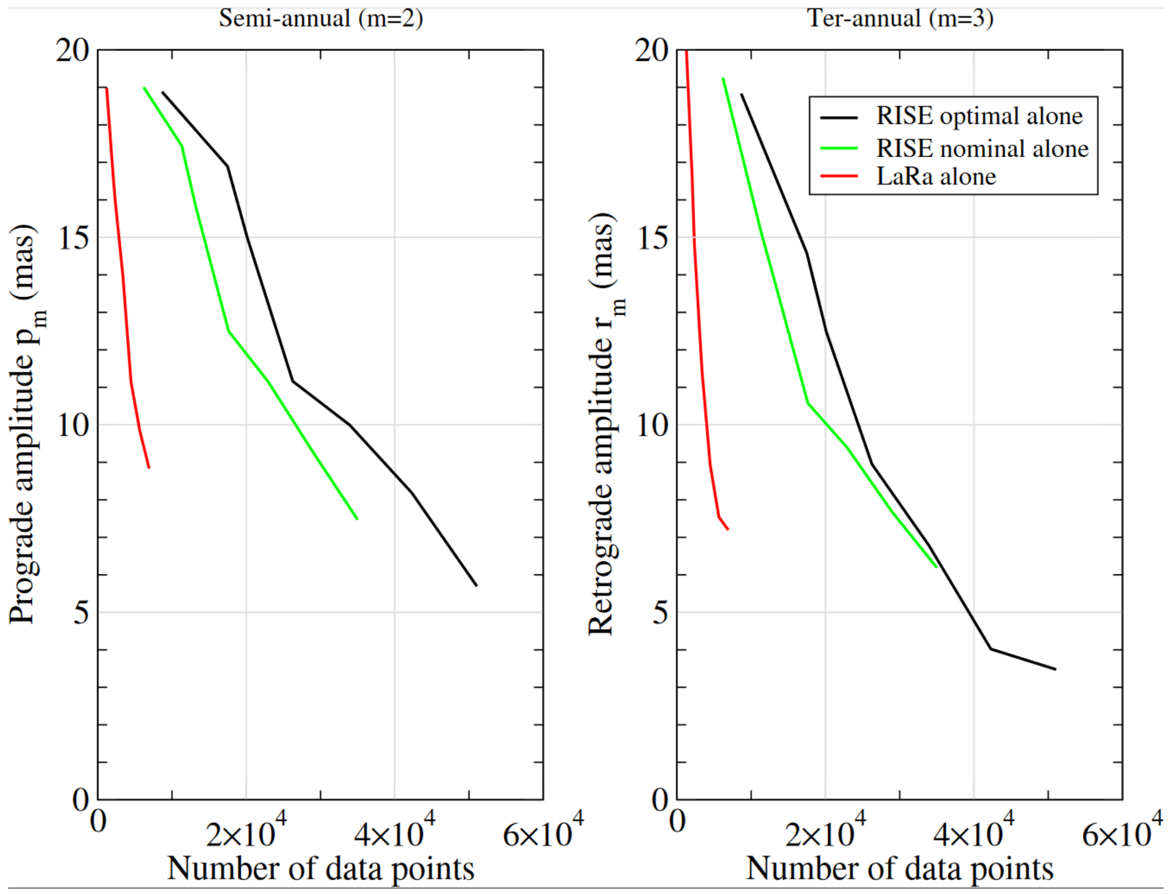
- Earth line of sight (LOS) geometry in terms of elevation and azimuth



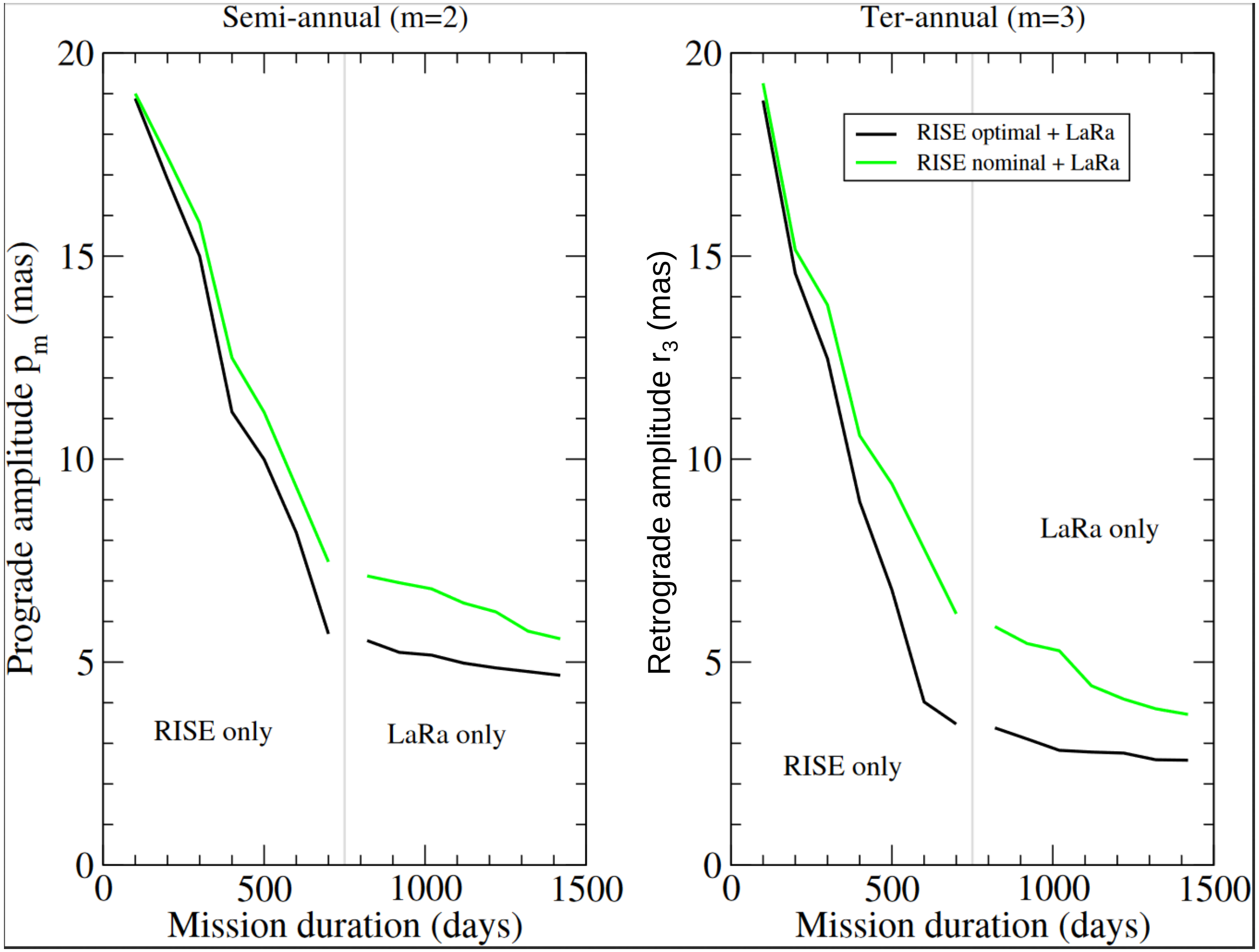


Simulations results

➢ Impact of the number of data points on the nutation uncertainties as estimated by RISE optimal case, RISE nominal case and LaRa separately

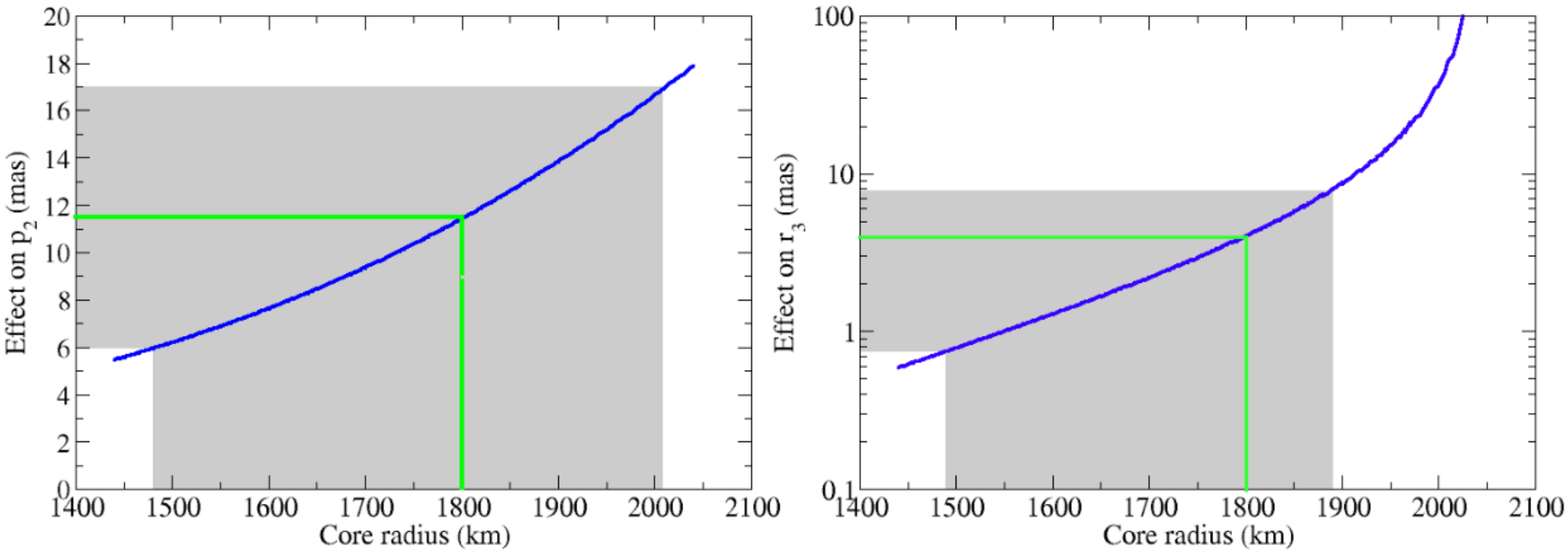


➢ Impact of the synergy between RISE and LaRa on the nutation uncertainties for the nominal RISE optimal case and the RISE nominal case followed by LaRa.



Implication for Mars interior

- The liquid core effect on p_2 and r_3 nutation amplitudes as a function of core radius.
- If r_{cmb} = 1800 km, uncertainties coming from synergy lead to an uncertainty of about ± 250 and ± 200 km on the core radius.



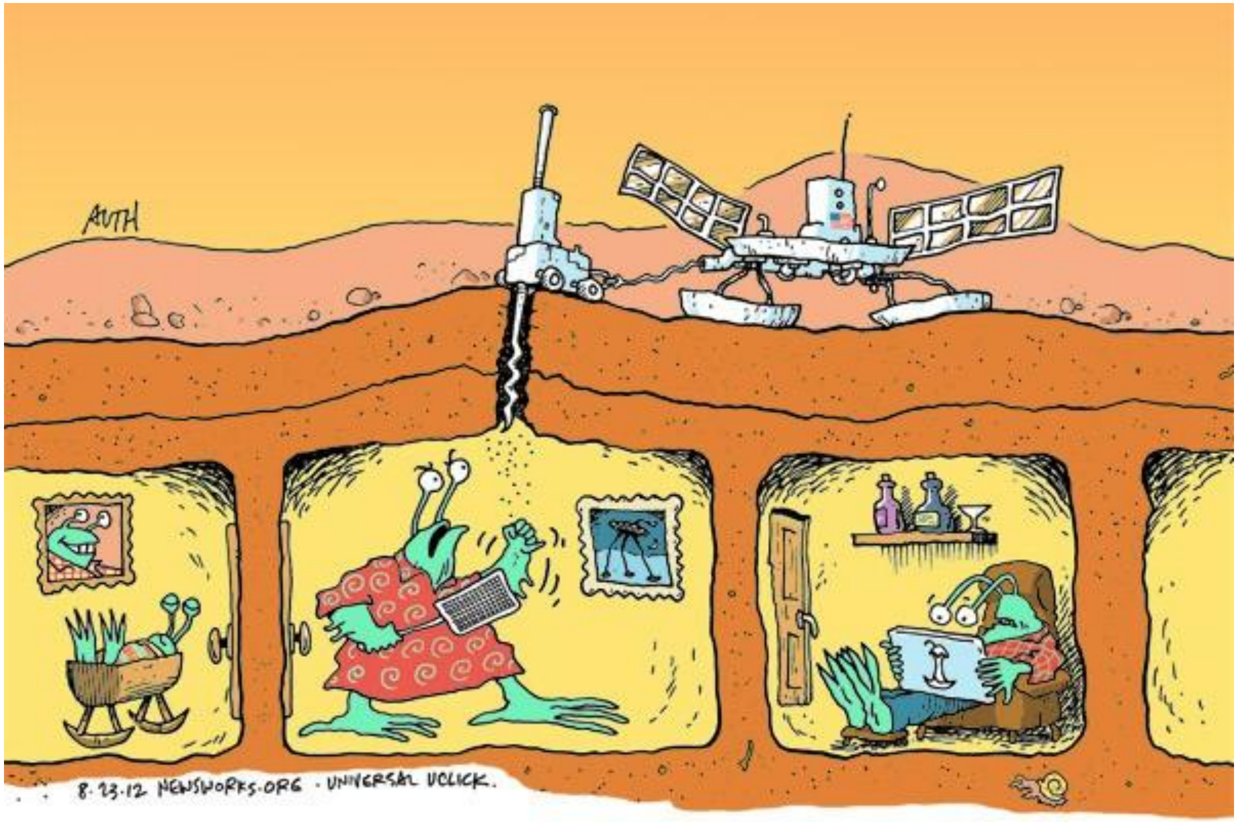
Conclusion

- By combining 700 nominal RISE tracking days with 700 LaRa tracking days, we achieve a precision of 5.5 mas and 3.75 mas for the semi-annual prograde and the ter-annual retrograde nutations amplitudes respectively.

- Although LaRa will operate 5-7 times less than RISE, LaRa has the advantage of its richer geometry which compensates the limited amount of data.

- The contribution of LaRa (even if small) in MOPs determination can have a significant impact on the constraints inferred on the core size.

Merci de votre attention !



Earth declination