ExoMars **La**nder **Ra**dioscience (LaRa), a Space Geodesy Experiment to Mars

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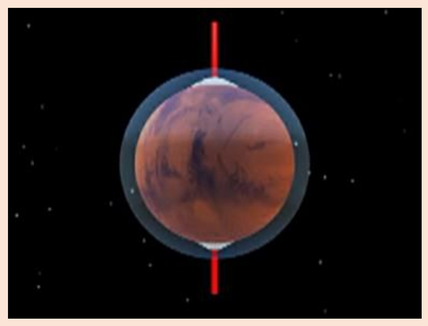
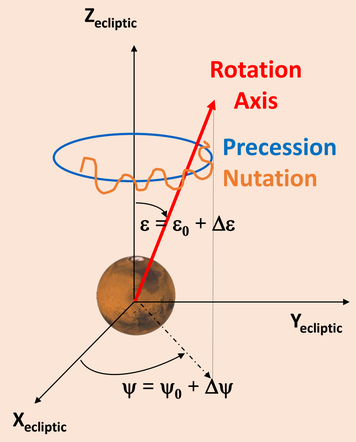
Objectives

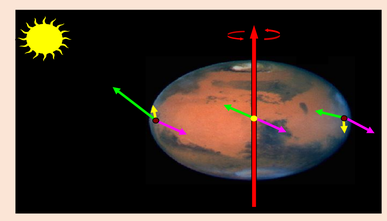
- Orientation in space
  → precession & nutation
- Orientation in planet
  → polar motion
- Rotation rate
  → length-of-day variations

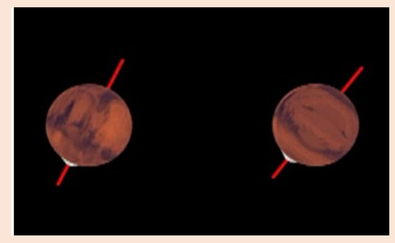
➡ Modeling of
- interior of planets
- atmosphere dynamics (CO_2 sublimation/ condensation process)

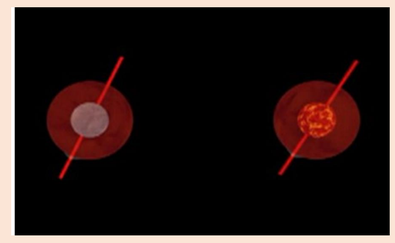


➡
- core density
- core dimension
- core state
- interior evolution
- habitability

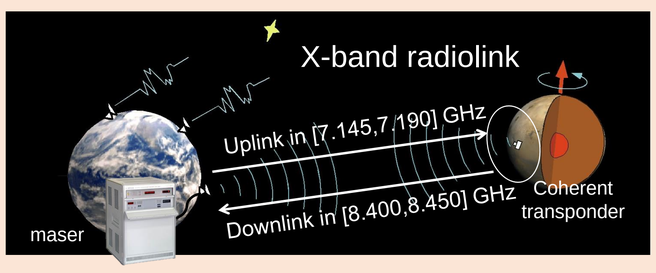




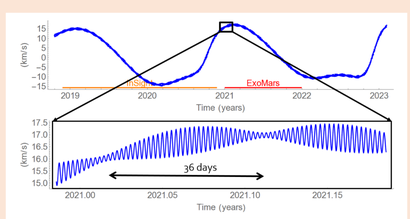




Principle of the experiment

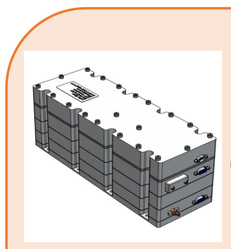


Two-way Doppler measurements between a lander on Mars and a ground station on Earth
Frequency reference (maser) on Earth



Doppler effects related to the revolutions and rotations of Mars and the Earth

Instrument



Coherent transponder (no instrumental phase) in X-band

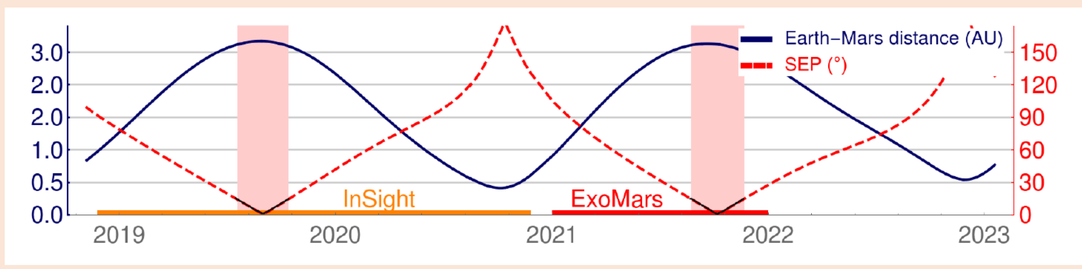
Uplink at 7173.87 MHz (Earth-to-space)
Downlink at 8428.58 MHz (space-to-Earth)

One RX antenna receiving from Earth
Two TX antennas transmitting to Earth
Elevation for observation [30°,45°]

Large antennas at ground station

Link budget so that at long distances, ground stations can lock on the signal
- closed-loop Doppler receiver
- open-loop receiver when SNR (Signal-to-Noise Ratio) too small

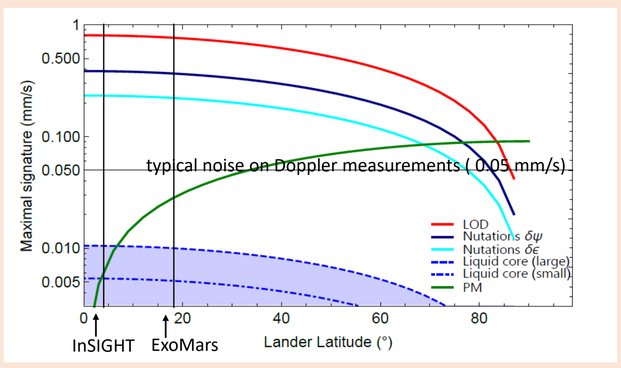
⟷ 64m / 70m antennas for long distances between Mars and Earth and 34m / 35m antennas at smaller distances (NASA DSN, Roscosmos Ground Stations, ESA ESTRACK tracking stations)



Simulations

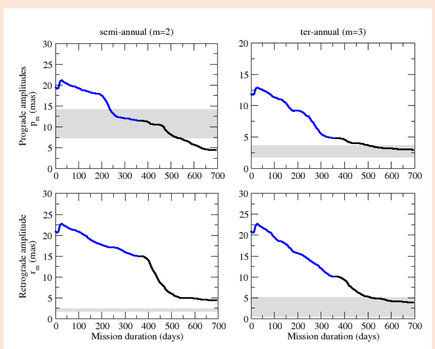
We investigated the signature in the Doppler of Mars Orientation Parameters from which we determined strategies of observation and of data analysis.
These signatures and strategies are related to:
- Amplitude of nutations, Amplitude of liquid core contribution to nutations
- Amplitude of LOD variations
- Amplitude of Polar motion
- Dependence on lander latitude and longitude,
- Dependence on mission duration
- Aptitude to communicate or visibility

We further studied the synergies with other missions:
- InSIGHT (Interior exploration using Seismic Investigations, Geodesy, and Heat Transport) / RISE (Rotation and Interior Structure Experiment) & SEIS → interior of Mars
- TGO (Trace Gas Orbiter) → atmosphere of Mars



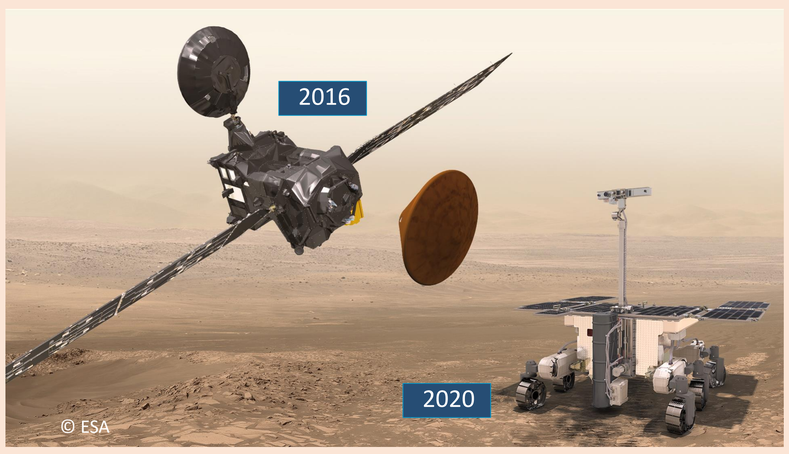
Maximal signature in the Doppler observable as a function of the lander latitude

Mars Orientation Parameters (MOP)	Model	Max. MOP amplitude	Max. change in the lander position	Geophysical Properties
Nutation in obliquity (δε)	Trigonometric series (annual, ½, 1/3, …)	10.3 m	10.3 m	C_f (Mars core moment of inertia) Core state, core size, core density
Nutation in longitude (δψ)	Trigonometric series (annual, ½, 1/3, …)	29.4 m	12.3 m	
Liquid Core effect	Liquid core amplification in the nutations	0.7 m on dψ, 0.4 m on dε	0.4 m	
Precession Rate (uncertainty of 2 mas/y)	Rate	0.8 m	0.8 m	C (Mars moment of inertia)
Length-of-day (LOD) variations	Trigonometric series (annual, 1/2, 1/3, …)	11.8 m	11.8 m	Atmosphere and ice caps dynamics
Polar motion (PM)	Trigonometric series	1.2 m	1.2 m	



Estimated uncertainties on the amplitudes of the semi- and ter-annual pro- and retro-grade nutation as a function of the mission duration. The uncertainties are superimposed with the expected effect that a planet with a liquid core would have on those nutations (grey boxes).

At least 250 days of mission are necessary to detect the liquid core signature in the semi-annual prograde amplitude and at least 500 days to get it in the ter-annual retrograde amplitude.



Conclusions and expectations

LaRa is a Belgian instrument selected on the ExoMars 2020 surface platform of Roscosmos/ESA mission.
LaRa will provide information on interior of Mars, its evolution, as well as CO_2 sublimation/condensation process between the atmosphere and the ice caps.

Additional simulations (not presented here) in showed that:
- synergies between InSIGHT / RISE and LaRa are very valuable;
- synergies with all atmospheric data are very valuable too.

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