

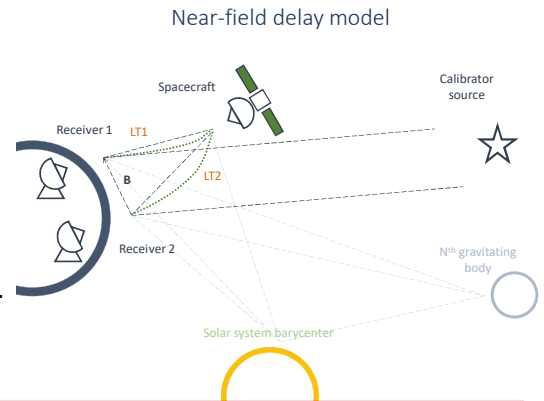
Ground-based VLBI observations for planetary missions

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Planetary Radio Interferometry and Doppler Experiment (**PRIDE**) is able to provide highly accurate estimates of the state vectors for the orbiters and landers by means of Very Long Baseline Interferometry (VLBI). This technique combines the observations of a network of radio telescopes to reach extremely high angular resolution.

PRIDE has been selected as one of the experiments of ESA's mission JUpiter ICy moons Explorer (JUICE).



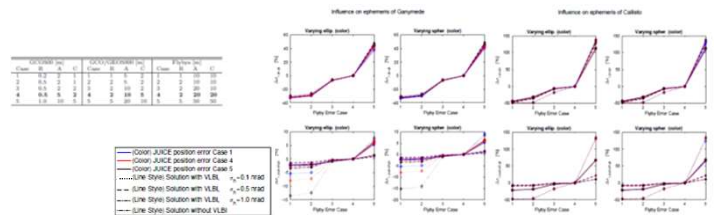
VLBI and ephemeris in the Jupiter system

(Dirkx et al 2017 - <https://doi.org/10.1016/j.pss.2017.09.004>)

By means of a covariance analysis, we simulated the accuracy to which the ephemerides of the Galilean moons can be determined from 3GM, PRIDE, JANUS and Navigation Camera of the **JUICE** mission. Then we assessed that the main contributions of the VLBI data to the generation of the ephemerides of the Jovian system are:

- The strong improvement of the out-of-plane component of the ephemerides, particularly for Ganymede and Callisto.

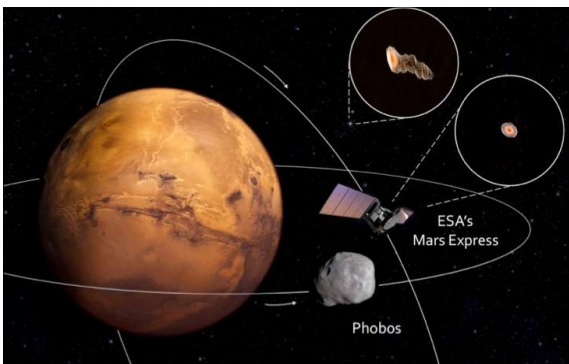
Measurement case	Relative initial position formal errors [%]							
	Ganymede		Io		Europa		Callisto	
	IP	OP	IP	OP	IP	OP	IP	OP
JUICE Position Error Case 1, $\sigma_h=0.1$ nrad	-10.1	-80	—	—	-51.3	-66.8	-63.2	-95.9
$\sigma_h=0.5$ nrad	—	-39.7	—	—	—	-18.2	-60	-85.2
$\sigma_h=1.0$ nrad	—	-18.3	—	—	—	-9.24	-57.9	-73.9
JUICE Position Error Case 4, $\sigma_h=0.1$ nrad	-9.04	-81.2	-7.72	—	-54.6	-79.1	-66.6	-97.3
$\sigma_h=0.5$ nrad	—	-43.1	—	—	-14.1	-32.1	-60.7	-91.6
$\sigma_h=1.0$ nrad	—	-21.3	—	—	—	-15.4	-59.7	-84.7
JUICE Position Error Case 5, $\sigma_h=0.1$ nrad	-18	-95.1	—	—	-61.1	-85.9	-70.9	-98.2
$\sigma_h=0.5$ nrad	—	-83.4	—	—	-16.8	-50.3	-63	-95.9
$\sigma_h=1.0$ nrad	—	-69.2	—	—	-5.95	-26	-61.2	-93.2



- The reduction of the influence of the orbit determination quality of the JUICE spacecraft on the uncertainty of the ephemerides.

Phobos' flyby

(PI – P. Rosenblatt, Duev et al 2016)



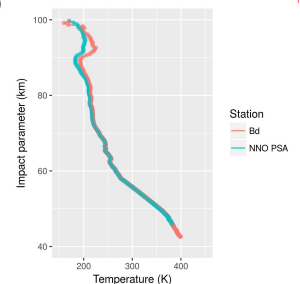
Formal precision (3σ):
RA 34 μ as \rightarrow 35 m
Dec 58 μ as \rightarrow 60 m

Doppler detection noise
10 s integration: 30 μ m/s

Venus Atmospheric profiles

(Bocanegra et al in preparation)

The profiles of Venus ionosphere and neutral atmosphere obtained with VLBI telescopes are comparable with Estrack observations.



It is worth to notice that our measurements may allow us to probe lower atmospheric levels, which can be important for scientific applications.

PRIDE use of on board instruments:

- Transmitter(s) and/or transceiver(s)
- Antenna

Earth-based assets of PRIDE are:

- Network of radio telescopes
- Specialized data processing center

None of the above is a PRIDE-only device