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Juno radio science observations to constrain Jupiter's moment of inertia

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Abstract

Through detailed and realistic numerical simulations, the present study assesses the precision with which Juno can measure the normalized polar moment of inertia (MOI) of Jupiter. Based on Ka-band Doppler and range data, this analysis shows that the determination of the precession rate of Jupiter is by far more efficient than the previously proposed Lense-Thirring effect to determine the moment of inertia and therefore to constrain the internal structure of the giant planet with Juno.

1. Context

Because of its huge gravitational attraction, Jupiter played the primary role in the formation and evolution of our Solar system. The interior structure and composition are fundamental clues to trace back the origin of the largest gaseous planet. They are therefore essential to be known to understand our Solar System.
The moment of inertia characterizes the mass concentration towards the center of the planet. It is therefore a valuable quantity to provide constraint on the interior structure and especially on the mass and size of the hypothetic core of Jupiter.

2. The Juno mission

The Juno mission en route to Jupiter aims to study the planet's composition and interior structure, gravity field, magnetic field, and polar magnetosphere in order to investigate the origin and evolution of the giant planet [1]. The mission characteristics are summarized in Table 1. Very recently, in the course of March this year, some of these characteristics have been modified; the 11-day orbital period has been increased to 14-days and the mission duration augmented from one Earth year to about 580-days.

Table 1: Juno's characteristics

Parameter	value
Orbital period	14-days
Eccentricity	e=0.95
Inclination	i=90°
Semi-major axis	a=1670000 km
Orbital plane	close to face-on
Frequency band	Ka-band (32.5GHz)
Doppler noise	10 μm/s@60s
Tracking station	DSS-25 (34-m at Goldstone)
Tracking duration	∼6h about pericenter
Jupiter orbit insertion	July 5, 2016
Nominal mission duration	580-days
Gravity science start	Nov. 11, 2016
Gravity science end	Jan. 23, 2018
Science/Gravity operations	32/26 passes

3. Pole precession rate estimate uncertainty

Using the JPL Orbit Determination Program, we carried out a variance/covariance analysis based on simulated Ka-band Doppler measurements from the Juno mission. We account here for a large number (>300) of parameters that will affect the orbital motion of Juno, including Jupiter's mass parameter (GM) and gravity field coefficients through degree 12, as well as several non-gravitational acceleration parameters (solar pressure, Jupiter infrared radiation, outgassing) and the Jupiter orientation parameters. Figure 1 shows the expected 1-σ uncertainty evolution as a function of the mission duration for 6 different operation scenarii, quantifying thereby the impact of the variation in tracking duration and repartition before (BPJ) and after (APJ) perijove.

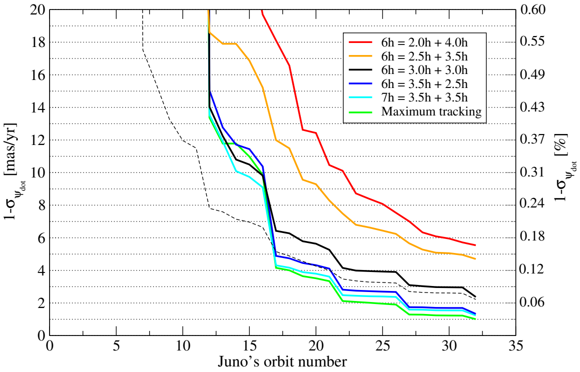

Figure 1: Time evolution of the 1-σ uncertainties in Jupiter spin axis precession rate as a function of the orbit number of Juno. The expected uncertainties obtained for each of the 6 tracking passes tested here are color-distinguished. Legends refer to tracking duration equals tracking BPJ plus tracking APJ in hours. Black thin dashed curve has been obtained with 6 hours of nominal tracking including all science pericenter passes, for comparison with the nominal black solid curve obtained with 26-gravity-dedicated passes.

4. MOI inferred uncertainty

Figure 2 shows that the normalized polar MOI will be inferred from the spin-pole precession rate of Jupiter at the same level of relative precision (i.e. $\sigma_{C/MR^2} \in [0.03\%, 0.17\%]$).

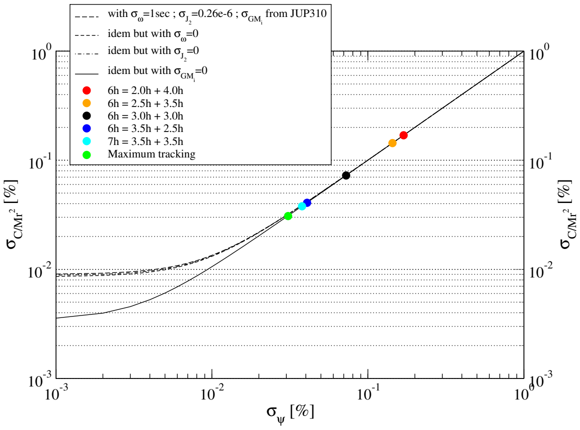

Figure 2: Jupiter's polar MOI relative precision inferred from the estimation of its pole precession rate.

5. Conclusions

We show that the determination of the pole precession rate allows for an MOI estimate about 50 times more precise than inferring it from the Lense-Thirring effect as proposed by previous studies.

In addition, we show that, given the actual tracking repartition and duration that will be performed to compute the orbit of Juno, the precision in the determination of the parameters can be increased (or decreased) by less than a factor of 3 wrt the 6h-periapsis-centered nominal tracking estimates. Such a quite small variation can however be critical in order to reach the goal of the mission and could have some consequences on the mission programmatic, depending on what will be the parameters of most interest.

We finally discuss in here the consequences of the last mission characteristic modifications (increase of the orbital period and mission duration) on the Juno's MOI estimate precision. Their implications for the detection of Jupiter's core if exists (likely) are addressed here as well as the ability to determine the core size and mass with enough precision to distinguish among competing scenarios for the planet's origin.

Acknowledgements

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