EPSC Abstracts
Vol. 13, EPSC-DPS2019-2019-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Jupiter's Gravity Field Estimated from *Juno* Data using the ORBIT14 software.

Daniele Serra (1), Giacomo Lari (1), Giacomo Tommei (1), Daniele Durante (2), Luis Gomez Casajus (3), Virginia Notaro (2), Marco Zannoni (3), Luciano Iess (2), Paolo Tortora (3).
(1) University of Pisa, Italy, (2) University of Rome La Sapienza, Italy, (3) University of Bologna, Italy
(daniele.serra@dm.unipi.it)

Abstract

The scope of the work is to present an independent solution of Jupiter's gravity field from *Juno* data, obtained with the orbit determination software ORBIT14 developed at the University of Pisa. The estimated gravity field is compared with the latest field available [3], obtained using the Jet Propulsion Laboratory software MONTE. The two solutions turned out to be fully consistent.

1. Introduction

The gravity experiment of NASA's *Juno* mission is aimed at determining Jupiter's gravitational field, a key element for the exploration of the giant planet's interior structure. A Ka-band Translator onboard the spacecraft allows a Ka-band radio link both in uplink and in downlink, ensuring very precise measurements of the orbiter's radial velocity (~ 3 μm/s at 1000 s integration time).

The latest estimation of Jupiter's gravity field [3] was obtained processing data from two *Juno*'s gravity orbits, namely PJ3 and PJ6, providing an improvement up to a factor 50 with respect to previous gravity field solutions obtained with the *Voyager* and *Galileo* missions. Such analysis was undertaken using the Jet Propulsion Laboratory software MONTE.

In this poster we present a solution of Jupiter's gravitational field obtained analyzing the same data from PJ3 and PJ6, but using a different software, the code ORBIT14 developed at the University of Pisa. Some mathematical models implemented in ORBIT14 are substantially different from MONTE's, making the two analyses independent one from another. Since the gravity fields estimated with the two programs turned out being fully consistent, the present solution indeed confirms the results about Jupiter's interior structure described in [4] and [2], based on [3].

2. The software ORBIT14

The orbit determination software ORBIT14 was designed specifically for the data analysis of the radio science experiment of ESA/JAXA's *BepiColombo* and NASA's *Juno* missions.

The main differences from the Jet Propulsion Laboratory software MONTE are in the relativistic approach for orbit propagation and in the formulation of the observable. As regards the former, ORBIT14 implements a multi-chart approach [1], considering different relativistic frames for different bodies, instead of a single chart for all Solar System bodies. The Doppler observable implemented in ORBIT14 differs from MONTE's by a change of variables and it is numerically calculated using a 7-node gaussian quadrature formula.

3. Dynamical models

Jupiter's gravitational potential is expressed in a Jupiter-fixed reference frame in terms of spherical harmonics [5]:

$$U = \frac{GM}{r} + \sum_{\ell=2}^{+\infty} \sum_{m=0}^{\ell} \frac{GMR^\ell}{r^{\ell+1}} [C_{\ell m} Y_{\ell m1} + S_{\ell m} Y_{\ell m0}], \tag{1}$$

where GM is Jupiter's gravitational parameter, R is Jupiter's equatorial radius, r is the distance from Jupiter's center of mass, $Y_{\ell mi}, i = 0, 1$ are the spherical harmonic functions, depending on the longitude and latitude, and $C_{\ell m}, S_{\ell m}$ are the spherical harmonic coefficients. The zonal coefficients are $J_\ell = -C_{\ell 0}$.

A complete and detailed description of the dynamical models for the *Juno* spacecraft and the Barycenter of the Jovian System can be found [6].

4. Experiment setup

The setup that we adopted is the same used in [3], in order to be able to compare the results. We analyzed both Doppler and range data from the two gravity orbits known as PJ3 and PJ6. The list of the estimated parameter is: Jupiter's zonal harmonic coefficients $J_2, \ldots, J_{24}$, the quadrupole $C_{21}, S_{21}, C_{22}, S_{22}$, the pole angles α_0, δ_0 at epoch J2000, the pole rate $\dot{\alpha}, \dot{\delta}$, the Love number k_{22}, the gravitational parameter GM, Jupiter System Barycenter's initial state, the spacecraft state for each PJ, one range bias for each PJ.

5. Results

Zonal coefficients of degree $\ell > 12$ had signal-to-noise ratio less than 1, therefore we report only a comparison of the zonal coefficients $J_2, \ldots, J_{12}$ (Fig. 1). About 80% of the estimated parameters turned out differing by less than the formal uncertainty (1σ), the others differing by less than 2σ. The formal uncertainties estimated by ORBIT14 were consistently larger than MONTE's, generally differing by less than 10%, only in a few cases up to $\sim 25\%$.

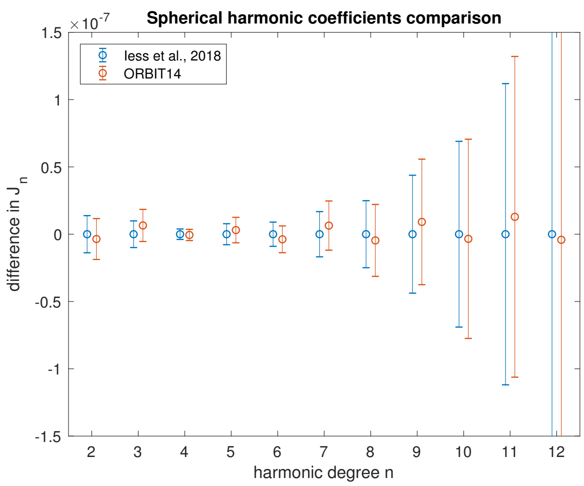

Figure 1: Comparison of Jupiter's gravity field solutions from MONTE [3] and ORBIT14. The first solution is taken as a reference and the second obe is represented as difference from the reference. Error bars are three times the formal uncertainty.

6. Summary and Conclusions

We have presented a solution of Jupiter's gravitational field, obtained by analyzing Doppler and range data from *Juno*'s gravity orbits PJ3 and PJ6 using the University of Pisa software ORBIT14.

The result was consistent with the solution published in [3], where the Jet Propulsion Laboratory software MONTE was employed. The difference between the estimated spherical harmonic coefficients values was smaller than the formal uncertainty in most cases, two times the formal uncertainty in the remaining ones.

In conclusion, the ORBIT14 independent solution of Jupiter's gravity field confirms all the discoveries about Jupiter interiors based on [3] and described in [4] and [2].

Acknowledgements

This research was funded in part by the Italian Space Agency (ASI).

References

[1] T. Damour et al.: General-relativistic celestial mechanics. Theory of satellite motion, Physical Review D, vol. 49, 1994

[2] T. Guillot et al.: A suppression of differential rotation in Jupiter's deep interior, Nature, vol. 555, pp-227-230, 2018

[3] L. Iess et al.: Measurement of Jupiter's asymmetric field, Nature, vol. 555, pp. 220-222, 2018.

[4] Y. Kaspi et al.: Jupiter's atmospheric jet streams extend thousands of kilometers deep, Nature, vol. 555, pp-223-226, 2018.

[5] W. Kaula: Theory of Satellite Geodesy, Dover, 1966.

[6] D. Serra et al.: Gravimetry, rotation and angular momentum of Jupiter from the Juno radio science experiment, Planetary and Space Science, vol. 134, pp.100-111, 2016.