EPSC Abstracts
Vol. 13, EPSC-DPS2019-1150-1, 2019
EPSC-DPS Joint Meeting 2019

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

Update on Jupiter's mass from Juno gravity and navigation data

Virginia Notaro, Daniele Durante and Luciano Iess
Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Rome, Italy
(virginia.notaro@uniroma1.it)

Abstract

The Juno spacecraft is currently on its nineteenth, 53.5-day orbit around Jupiter, studying the gas giant's gravity field, atmosphere and magnetosphere to gain understanding on its interior structure. To date, eleven orbits have been dedicated to the gravity experiment. The gravity measurements are carried out by measuring the Doppler shift of two-way microwave links sent to the spacecraft by NASA Earth stations at both X-band (7.2-8.4 GHz) and Ka-band (32.5-34 GHz) during a $\pm$ 3-hour window around the pericenter. The extraordinary level of accuracy achieved with Juno's Ka-band radio tracking system (0.01 mm/sec at 60-s integration time on the spacecraft two-way radial velocity) has resulted in the unprecedented determination of the asymmetric component of Jupiter's gravity field, which in turn allowed constraining the depth of the zonal winds [1, 2].

The geometry of observation during a gravity-dedicated pericenter passage maximizes the sensitivity of the Doppler measurements to Jupiter's gravity field. However, since the duration of the tracking passage is short compared to the orbital period, it is not possible to reliably separate the monopole component —proportional to the GM of the planet, the product between the gravitational constant G and the mass M—from the quadrupole. Numerical simulations of the Juno gravity experiment for the nominal duration of the mission have shown that Juno Ka-band data will indeed not improve the current knowledge of Jupiter's GM, obtained by analyzing the motion of the satellites [3, 4]. Nonetheless, Doppler data at X-band are also collected throughout the 53.5-day orbit for navigation purposes. The inclusion of X-band data has been predicted to improve the accuracy on the determination of Jupiter's GM by a factor of two at the end of the nominal mission, while providing very limited information on Jupiter's gravity field.

We report on preliminary results of the analysis of both Ka-band Doppler data and X-band Doppler and range navigation data from Juno collected during the first 2 years of the mission. We integrate the motion of the spacecraft over each orbit around the gas giant, solving for Jupiter's and the Galilean satellite's masses, as well as the gas giant's gravity field and pole position, following [1]. Over the course of the 53.5-day orbit, a series of attitude adjustment maneuvers are executed using Juno's Reaction Control System (RCS) thrusters to control the precession of the spacecraft's spin-axis and maintain the pointing of the high-gain antenna towards the Earth. These maneuvers must be included in the dynamical model of the spacecraft and solved for in the estimation process. We present different methods of accounting for the precession turn maneuvers in the estimation filter and compare the effect on the determination of Jupiter's GM. Noise in the Doppler link drives the accuracy of the estimated parameters. The main noise source for the X-band data comes from dispersive media such as interplanetary plasma and Earth ionosphere, with a strong dependency on the Sun-Earth-Probe angle (Figure 1). Despite the large noise variability, the addition of X-band data collected over the entire orbit still increases the sensitivity of the measurements to Jupiter's GM by providing observations at different distances from the planet.

Although not amongst the primary science objectives of the gravity experiment, an improvement in the determination (value and uncertainty) of Jupiter's mass would be important for the development of planetary and satellite ephemerides and for future navigation and radio science experiments of Solar System probes.

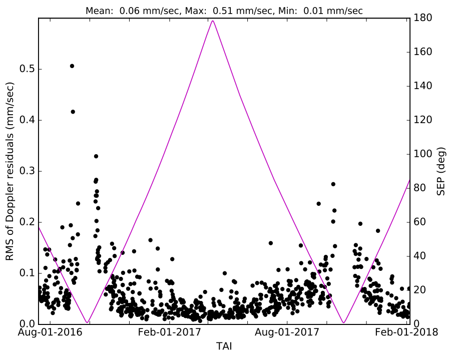

Figure 1: RMS of Juno X-band Doppler residuals for the first 1.5 years of the science mission, plotted against the Sun-Earth-Probe (SEP) angle (purple line).

Acknowledgements

The authors acknowledge sponsorship from the Italian Space Agency (ASI).

References

[1] Iess, L., Folkner, W.M., Durante, D., Parisi, M., Kaspi, Y., Galanti, E., Guillot, T., Hubbard, W.B., Stevenson, D.J., Anderson, J.D., Buccino, D.R., Gomez Casajus, L., Milani, A., Park, R., Racioppa, P., Serra, D., Tortora, P., Zannoni, M., Cao, H., Helled, R., Lunine, J.I., Miguel, Y., Militzer, B., Wahl, S.M., Connerney, J.E.P., Levin, S.M., Bolton, S.J.: Measurement of Jupiter's asymmetric gravity field, Nature, Vol. 555, pp. 220-222, 2018.

[2] Kaspi, Y., Galanti, E., Hubbard, W.B., Stevenson, D.J., Bolton, S.J., Iess, L., Guillot, T., Bloxham, J., Connerney, J.E.P., Cao, H., Durante, D., Folkner, W.M., Helled, R., Ingersoll, A.P., Levin, S.M., Lunine, J.I., Miguel, Y., Militzer, B., Parisi, M., Wahl, S.M.: Jupiter's atmospheric jet streams extend thousands of kilometres deep, Nature, Vol. 555, pp. 223-226, 2018.

[3] Serra, D., Dimare, L., Tommei, G., Milani, A.: Gravimetry, rotation and angular momentum of Jupiter from the Juno Radio Science experiment, Planetary and Space Science, Vol. 134, pp. 100-111, 2016.

[4] Jacobson, R. A., JUP310 orbit solution (available at naif.jpl.nasa.gov/pub/naif/generic_kernels/spk/satellites/).